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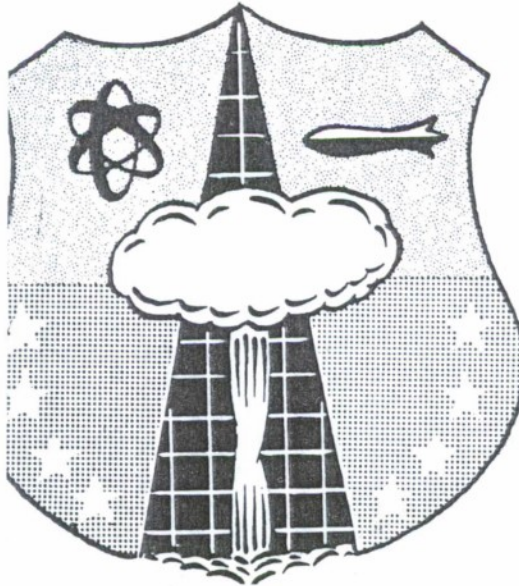
HEADQUARTERS

AIR FORCE SPECIAL WEAPONS CENTER

AIR RESEARCH AND DEVELOPMENT COMMAND

KIRTLAND AIR FORCE BASE, NEW MEXICO

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Volume I

HUMAN FACTORS HANDBOOK

For Design of Transporting, Positioning
and Lifting Ground Support Equipment

by

George L. Murphy
Paul H. Newman

AMERICAN INSTITUTE FOR RESEARCH

April 1959



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HUMAN FACTORS HANDBOOK
FOR DESIGN OF TRANSPORTING, POSITIONING
AND LIFTING GROUND SUPPORT EQUIPMENT

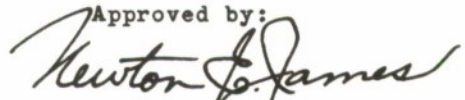
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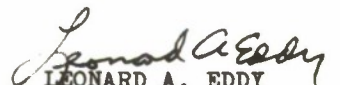
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ABSTRACT


This handbook, Volume I in a series of three, has been prepared for designers of Transporting, Positioning, and Lifting Equipment used to support airborne weapons. Volume II is concerned with Testing and Monitoring Equipment; Volume III, with Protective and Storage Equipment. The three volumes are intended as guides for the military or industrial designer who translates an idea into drawings and eventually into actual equipment. They may also be useful to persons preparing specifications for proposed equipment or evaluating such specifications. Each volume is meant to be self-sufficient and for this reason some duplication of material from book to book has been judged necessary.

The chapter headings in Tables of Contents show in general the types of equipment discussed in each handbook. An Index in each book contains page references to aid the user in locating information on specific components. A selected bibliography has also been included in each book, for use if detailed source information is needed beyond that found in the handbook.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:



CAREY L. O'BRYAN, JR.
Colonel USAF
Chief of Staff

FOREWORD

The term "human engineering" has been used in recent years to characterize the work of specialists who assist engineers in the design of equipment for human use. Equipment has always been designed for human use, but only with the advent of modern weapon systems has it become apparent that designing for human use implies a need for specialized knowledge of human capabilities and limitations. Whether one considers the term "human engineering" an apt title or a misnomer--and there will be controversy over this for years to come--modern weaponry has underscored the requirement for the inputs this young and growing discipline can make to equipment design. Given the size, complexity, and costs of the weapon systems of today and tomorrow, it has become essential that equipment be so designed as to minimize the likelihood of human error in operation and maintenance, to minimize needs for training and special skills, and to maximize safety and efficiency.

To meet these needs, human engineers have striven to develop "working principles" which embody the best recommendations they can make to engineers responsible for design and development. These "working principles" have come from knowledge of man's mental and physical capacities, from experimental studies of human responses to various types of stimulus conditions, and from observations of man as a functional component in an operational system.

There is a vast amount of literature available to the design engineer who wishes to incorporate human factors principles into his equipment design, but searching this literature constantly would place an unreasonable burden on the engineer. The literature should be summarized for him and made available in a form readily usable and meaningful. That is the purpose of this handbook and its two companion volumes.

Future investigations can be expected to yield more information on human behavior pertinent to the design of ground support equipment, and to confirm or force revision of some working principles which are presently best guesses. Periodic review of these handbooks is recommended so that new information can be incorporated as it becomes available.

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CHAPTER I

GENERAL CONSIDERATIONS IN THE DESIGN OF TRANSPORTING, POSITIONING, AND LIFTING EQUIPMENT

Design recommendations contained in this chapter cover those items which are common to most transporting, positioning, and lifting equipment. Included are considerations of over-all equipment configuration and design of doors and escape hatches, fuel tanks, accesses and replaceable units. The emphasis is on major structures and sub-units common to more than one type of equipment.

The design engineer must evaluate each of his design decisions in the light of its over-all system effect. Obviously, a change in one part of the system has far-reaching effects on other aspects of the system. Malfunctions and failures which might occur are evident in the early design stages. Safeguards against such malfunctions can be designed into the system, but sometimes at great expense. It is thus important that the designer analyze the effects on the system and/or on the operator of all possible malfunctions (by actual test if necessary). After such an analysis the designer can then decide on the best course of action. It may be possible or feasible to eliminate the malfunction or include redundant components to take over functions. On the other hand, he may decide on a periodic replacement procedure or may merely specify remedial action in case of breakdown. The specific nature of operator and maintenance tasks will depend on decisions the designer makes at this time.

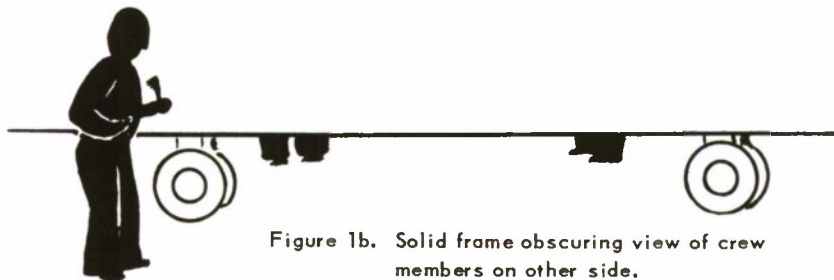
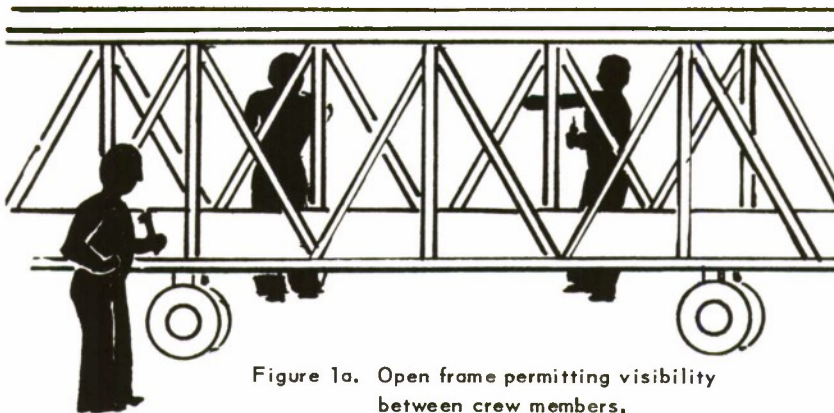
SECTION A. OVER ALL CONFIGURATION

Any piece of transporting, positioning, or lifting equipment is designed to carry, position, or lift some type of store--a bomb, missile or rocket. In some cases one piece of equipment will combine all three of these functions. In other cases, equipment will be designed for one specific function. In any event, the designer must consider such things as general appearance of the equipment, size and weight of the complete structure as well as its individual components, and the placement of individual components within the structure.

FRAMES AND STRUCTURAL MEMBERS

1. FRAMES SHOULD BE DESIGNED SO THAT VISIBILITY BETWEEN TEAM MEMBERS IS NOT IMPAIRED.

- a. Make use of openings in frames where possible so that the man at each operating position can see all four corners of the equipment. (See Figure 1)
- b. Keep height of frames to the necessary minimum so that the standing operator can see over the frames.
- c. If other solutions are not feasible, consider the use of mirrors to give all team members optimum visibility. (For loading in aircraft bomb bays, a mirror might be a piece of auxiliary equipment.)



2. DESIGN MOVING STRUCTURAL ELEMENTS TO AVOID STICKING AND BINDING, HAZARDS TO OPERATOR, AND HINDRANCE TO OTHER OPERATORS.

- a. Eliminate (or guard) sharp cutting edges where two moving elements come together.
- b. Incorporate design features to prevent operators from placing any part of their bodies where moving parts come together. (See Figure 2)
- c. Place operating controls for moving elements so that operator can see all parts of the moving structure while it is being manipulated.
- d. Place other controls, adjustments and connections so that the operation of the moving element does not interfere with their manipulation.

Case in Point

On one trailer, operation of the lift arms had to be halted while another crew member made a trailer positioning adjustment because the positioning controls were located where it was necessary to reach across the lift arms to get at them.

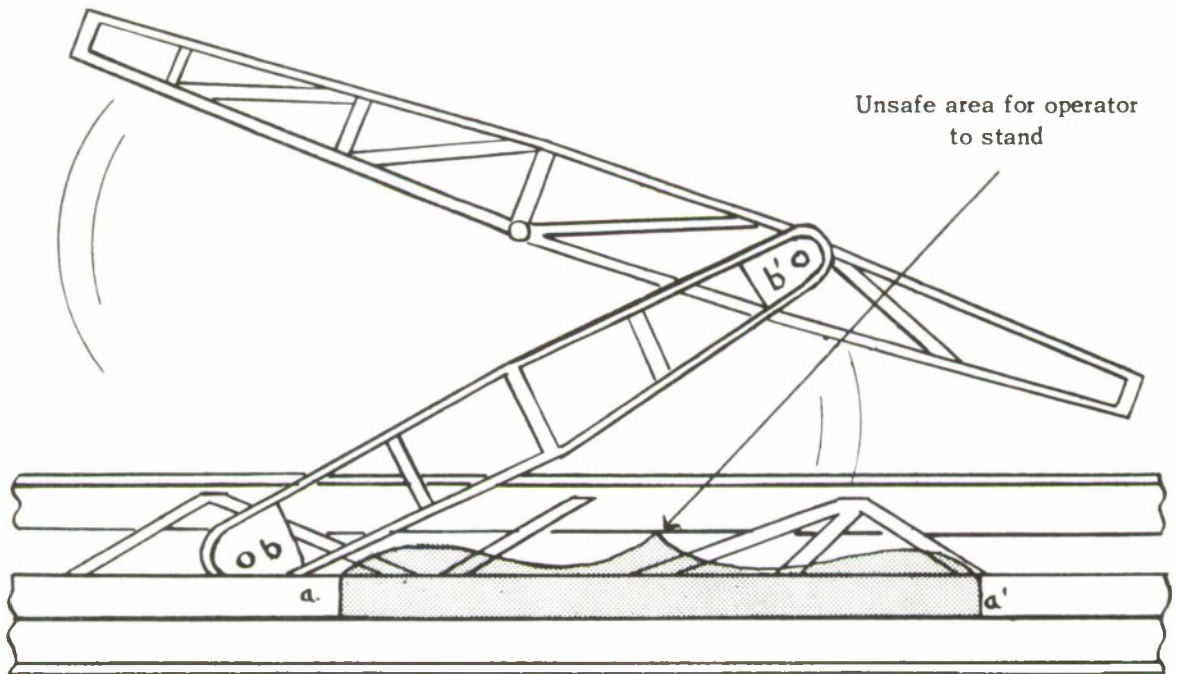


Figure 2

e. Provide sufficient clearances between moving structural elements to allow for all expected environmental conditions. Binding and sticking caused by changes in temperature and humidity may delay operations or require time-consuming retrofit.

f. Incorporate FAIL-SAFE features into all moving elements so if hydraulic or electrical power is lost, gravity will not permit a structure member to fall, causing personnel injury or equipment damage.

The design of FAIL-SAFE features should be such that their presence is not an inconvenience to the operator. If such features cause the operator inconvenience, he is likely to remove or by-pass them. Where possible, FAIL-SAFE features should be designed so that they are not removable or amenable to by-pass.

3. DESIGN STRUCTURAL ELEMENTS TO PROVIDE PROTECTION (FOR COMPONENTS AND PERSONNEL) AGAINST ENVIRONMENTAL FACTORS.

a. When equipment is to be operated under extremes of temperature and the operator must maintain his position for extended periods of time, surround the operator with an enclosure.

b. Enclosures should have suitable drip troughs to prevent water from draining on personnel or equipment.

c. Provide mud-guards, screens, and other protective devices to prevent mud, water, snow, and other extraneous material from damaging equipment or coming in contact with operating personnel.

4. DESIGN FRAMES AND STRUCTURAL MEMBERS TO AVOID HAZARD TO OPERATORS.

a. Avoid projecting edges, protrusions, rails, or corners on which operators may injure themselves. Where such protrusions are unavoidable, provide bumper guards and covers.

Covers and bumper guards should be of a material that is not susceptible to climatic damage and should be firmly attached to last the lifetime of the equipment.

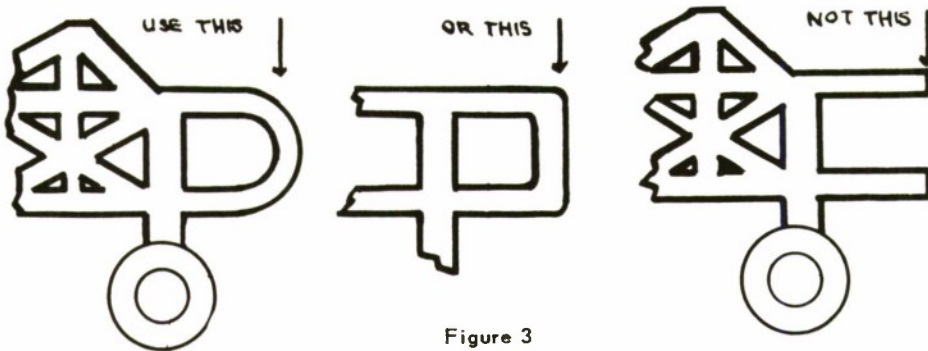


Figure 3

b. Place moving parts such as belts, chains, gears and linkages, where operational and maintenance personnel are least likely to come in contact with them. If there is any danger of personnel contact, guards should be provided.

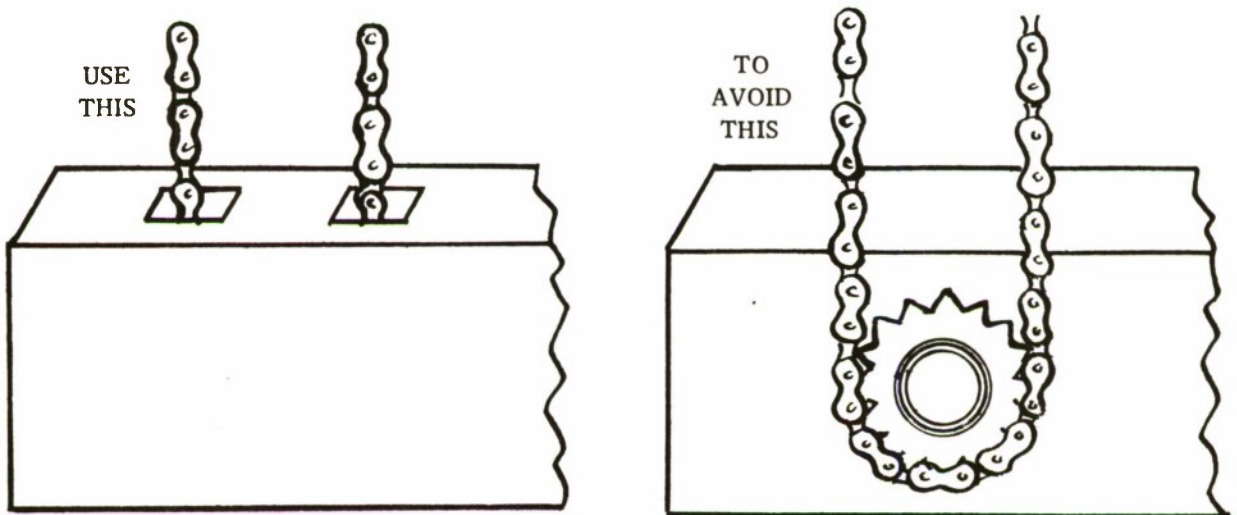


Figure 4

c. Insulate or place guards around high-voltage areas.

d. Provide protection against personnel coming in contact with components which generate high temperatures. Protection may be provided by careful placement of the component or by designing appropriate guards.



e. Where hinged devices are attached to the structure, and there are not overriding reasons for hinging at the bottom, place hinges at top to prevent device from injuring personnel in case of accidental unlatching. (See Figure 5.)

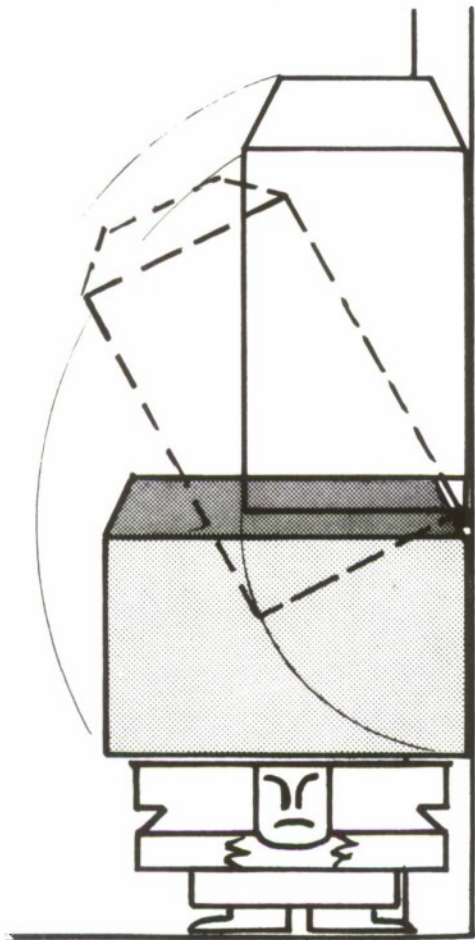


Figure 5

5. DESIGN PROPER TOLERANCES INTO EQUIPMENT

- a. Do not design in closer tolerances than necessary.
- b. Allow wide ranges of tolerances for items subject to extremes of adverse operational conditions.
- c. Make tolerances sufficient to accomodate all the various sizes and characteristics of any one type of article.

Allow room for paper or mica resistors, plastic or metal shields, different sizes of spark plugs and batteries. The battery tray in Figure 6, for instance, can be used with batteries of several different sizes.

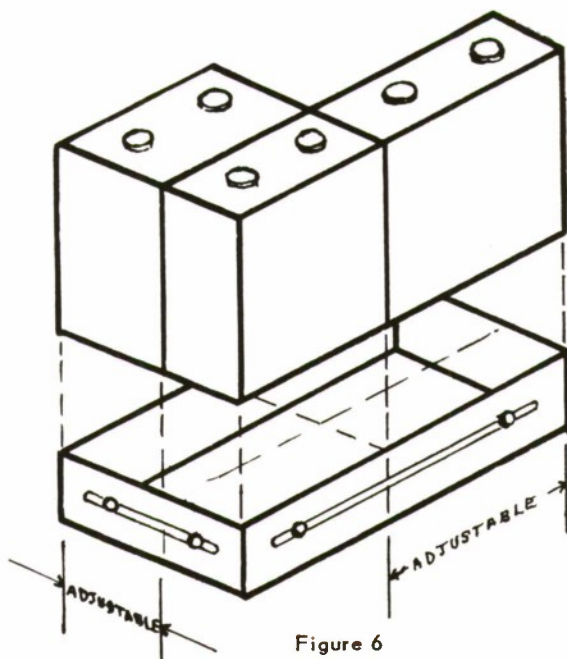


Figure 6

6. WHEN EQUIPMENT IS DESIGNED TO BE USED FOR SEVERAL DIFFERENT PURPOSES, LABELING SHOULD BE PROVIDED TO GIVE OPERATOR SUFFICIENT INFORMATION.

- a. When one unit can be adjusted to fit a number of situations, clearly label each adjustment according to the situation.

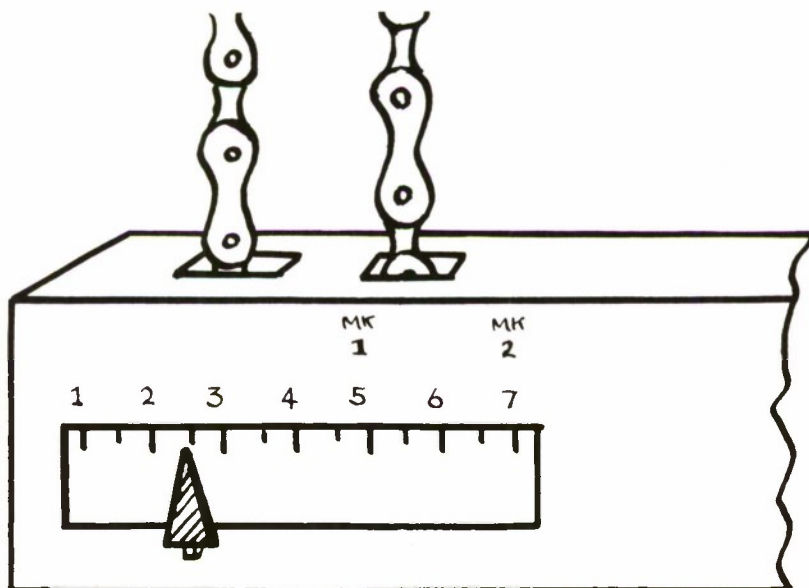


Figure 7



For example, a hoist beam may be used with several different weapons, each having a different center of gravity. If there is a scale on the beam which must be adjusted to different positions for each weapon, the weapon designation (Mk 1, Mk 2, etc.) should be marked at the appropriate positions on the scale.

7. WHEN MAJOR ELEMENTS OF THE EQUIPMENT WILL FREQUENTLY BE REMOVED, PROVISIONS FOR SUCH REMOVAL SHOULD BE MADE IN THE DESIGN.

- a. Enclosures, or major portions thereof, should be readily removable for maintenance operations.
- b. When weight of items is such that they cannot be readily handled by two men, provide for lifting by means of mechanical handling equipment.
- c. Hoisting provisions should be provided for all equipments requiring removal or replacement which are of such a size, weight, or location that they cannot be readily handled by one man.

SIZE, WEIGHT, AND GENERAL APPEARANCE

8. GENERAL APPEARANCE OF EQUIPMENT SHOULD BE DICTATED BY FUNCTIONAL UTILITY.

Non-functional embellishments should be avoided. Such additions to equipment often complicate maintenance, handling, and repair problems, and in some cases may actually create operator hazards.

9. WEIGHT AND SIZE SHOULD BE AS SMALL AS IS CONSISTENT WITH REQUIREMENTS SPECIFIED FOR THE EQUIPMENT.

Avoid weight which does not contribute to the performance of the equipment. This applies especially to trailers, bolsters, and other equipments which occasionally require manual positioning.

COLOR OF EQUIPMENT

10. COLOR SELECTED SHOULD ENABLE RAPID IDENTIFICATION OF EQUIPMENT TYPE OR USE.

- a. Recommended colors for various items of ground support equipment are given in MIL-S-8512.
- b. Surfaces should be painted with colors clearly distinguishable from each other.
- c. Interior color for GSE should be selected to facilitate visibility and maintenance of interior components and accessories.

NAME PLATES AND LABELS

11. ALL UNITS AND PARTS SHOULD BE LABELED WITH FULL IDENTIFYING INFORMATION.

Identify each item of Transporting, Positioning, and Lifting equipment with a securely attached name plate, permanently and legibly marked with information called for in MIL-S-8512.

12. DESIGN NAME PLATES AND LABELS FOR PERMANENCE AND LEGIBILITY.

a. Labels should be etched or embossed into components (or into plates to be attached to components) rather than being merely stamped on the surface.

If surface labels must be used, decals or stamped labels are preferred to stenciled labels, because they are usually easier to read.

b. In order to facilitate reading from a distance, make name plates and labels as large as is consistent with over-all size of equipment and include only necessary information.

Wherever possible, make height of letters and numerals at least one-quarter inch. One-tenth inch is minimum letter height for labels which must be read from as far away as three feet.

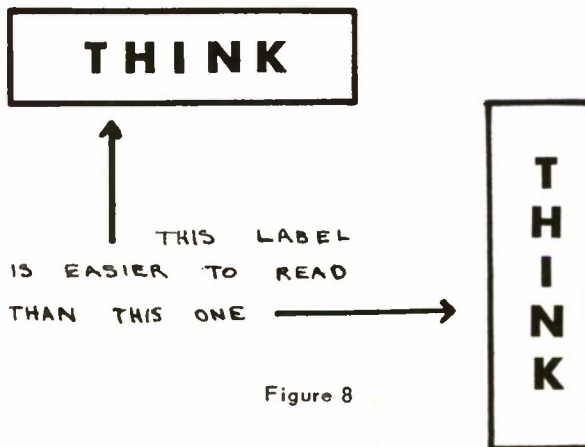


Figure 8

c. Design labels and name plates to be read horizontally, not vertically.

d. Use brief familiar wording.

e. Place labels so they are not hidden by units or parts. (Labels stamped on chassis should not be placed under the parts which they identify.)

f. For best legibility of labels, plates should have a dull surface.

(1) Color contrast between letters and plates should be maximum.

(2) Black lettering on a white background is preferred.



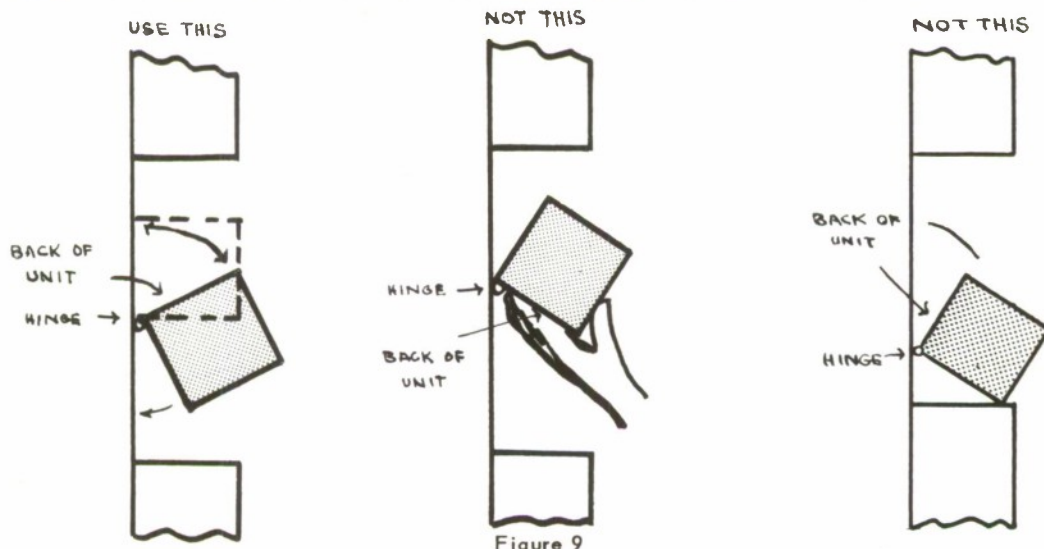
LOCATION OF INDIVIDUAL COMPONENTS

13. LOCATE EQUIPMENT COMPONENTS TO MINIMIZE POSSIBILITY OF EQUIPMENT DAMAGE OR PERSONNEL INJURY.

- Delicate components should be located where they will not be damaged while equipment is being worked on.
- Place components in positions where oil, other fluids, or dirt is not likely to fall on them or the technician working on them.
- High temperature parts should be guarded or should be located so that contact will not occur during normal operation. Heat producing equipment should be arranged and shielded so that discomfort to the operator is avoided.
- Enclose high current switching devices to protect handling personnel. Internal controls should not be located close to dangerous voltages or acids.

14. LAY OUT COMPONENTS SO THAT THEY ARE ACCESSIBLE TO BOTH OPERATING PERSONNEL AND MAINTENANCE TECHNICIANS

- Components maintained by the same technician should be grouped. They should be laid out so that during system checking, a minimum of moving from position to position is necessary.
- Place check points, adjustment points, cable-end connections, and labels so that they are in full view of the technician.
- Devices which must be manipulated during normal operation should be accessible by reach without stooping or stretching or use of auxiliary platforms.
- Let small hinge-mounted units which must have access to the back be free to open their full distance and remain open without being held. (See Figure 9.)



e. Make components and systems requiring frequent inspection and maintenance as accessible as possible.

- (1) Units should be located so no other equipment has to be removed to gain access to them.
- (2) Units should not be stacked. If it is necessary to stack units because of space limitations, the unit requiring less frequent access should be placed in the back or on the bottom.

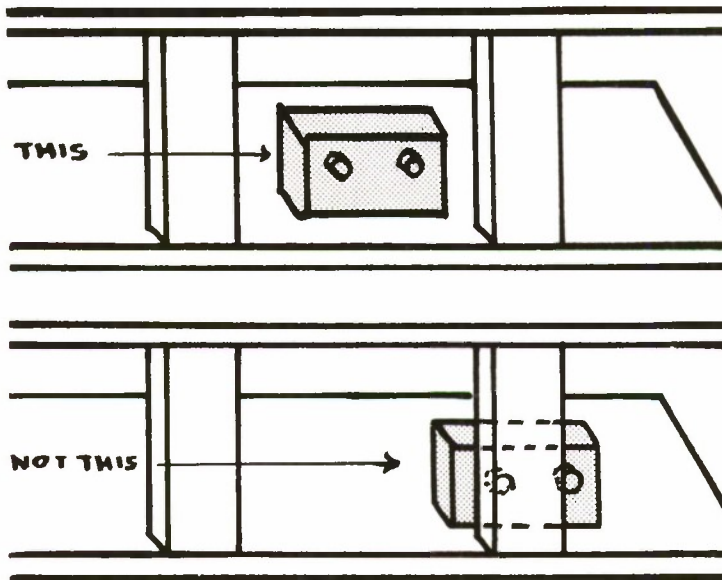


Figure 10

f. By judicious placement of components or design of frames and structural members, avoid the situation where frames and structural members interfere with maintenance and operational personnel reaching components they must maintain, inspect or operate.

g. Components which require frequent visual inspection should be installed in positions where they can be seen easily without removing panels, covers, or other units.

SECTION B. ACCESSES AND ACCESSIBILITY

The design recommendations in this section pertain to all kinds of accesses and to accessibility of various equipment components. The term accesses includes doors and escape hatches as well as accesses ordinarily used for inspection and maintenance. For those portions of transporting, positioning, and lifting equipment that are subject to frequent inspection and maintenance, accesses should be provided rather than having personnel constantly removing cases or covers, opening fittings and dismantling components to perform maintenance and inspection operations. To make such inspection and maintenance as easy and error free as possible, provide equipment inspection covers, zippers in cloth openings, and quick fasteners.



1. SELECTING TYPE OF ACCESS

a. For insertion of tools, test leads, and service equipment, an opening with no cover is preferred.

(1) If dirt and moisture are a problem, use a sliding or hinged door. Hinged doors should open downward to eliminate need for holding door open.

(2) When a door is not feasible because of stress requirements, specify a quick-opening cover plate.

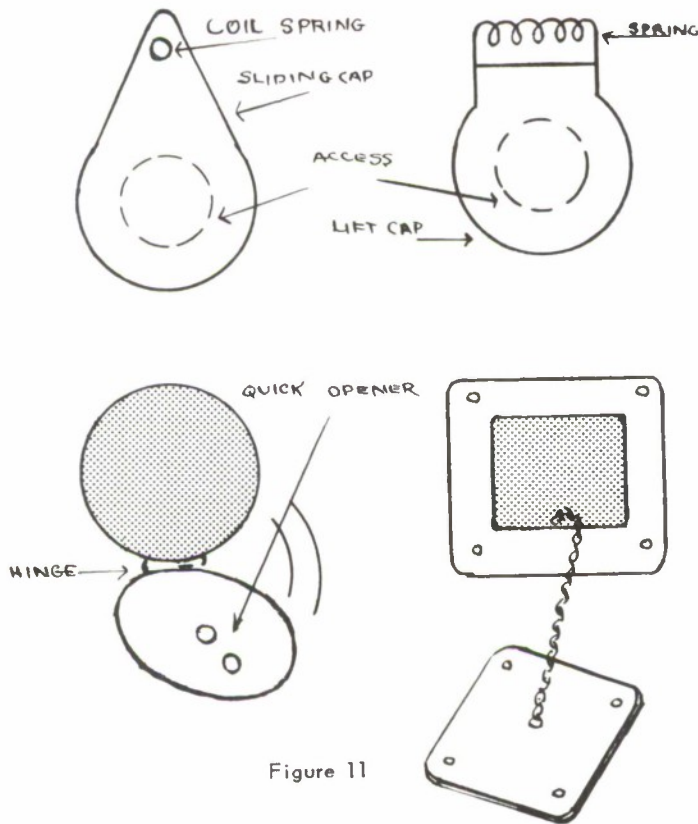


Figure 11

b. Access designed for visual inspection only should preferably also be an opening with no cover.

(1) A second choice (if dirt and moisture may be a problem) is an opening with a plastic window.

(2) If physical wear or contact with solvents would cause optical deterioration of plastic, specify break-resistant glass.

(3) Visibility and access will usually be provided through the same access. However, where complex tasks must be performed through small accesses past wrist insertion, separate visual accesses should be provided. (See Figure 12.)

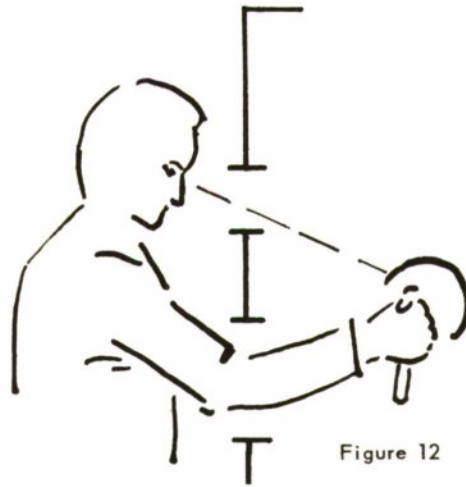
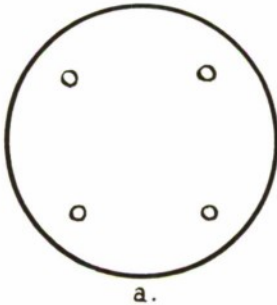


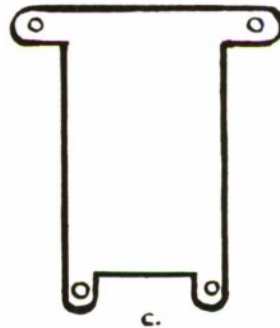
Figure 12

2. LOCATION AND SHAPE OF ACCESSES

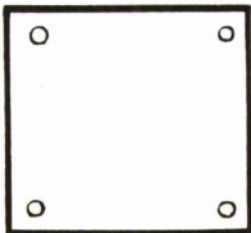
- a. Location is determined by the position of internal components and the way in which they must be installed.
- b. Accesses should be located to permit maximum convenience in performing job procedures. Insure that internal components are easily accessible.
- c. Determine which faces of equipment will be accessible in normal installation and place access on one of them.
- d. Shape should conform to the need for which the access was derived and should permit easy passage of components and tools. Other things being equal, accesses should be square.



a.



c.



b.

Round or square accesses (a and b) may be attached in several different ways; odd shaped accesses (c) can be attached only in one way.

Figure 13



HOWEVER—If a removable access plate must be attached in a certain way, the shape should be such as to prevent incorrect attachment. (See Figure 13)

In the example pictured below an aircraft inspection door was replaced incorrectly, causing the flap control system lever to jam against the inspection door reinforcement.

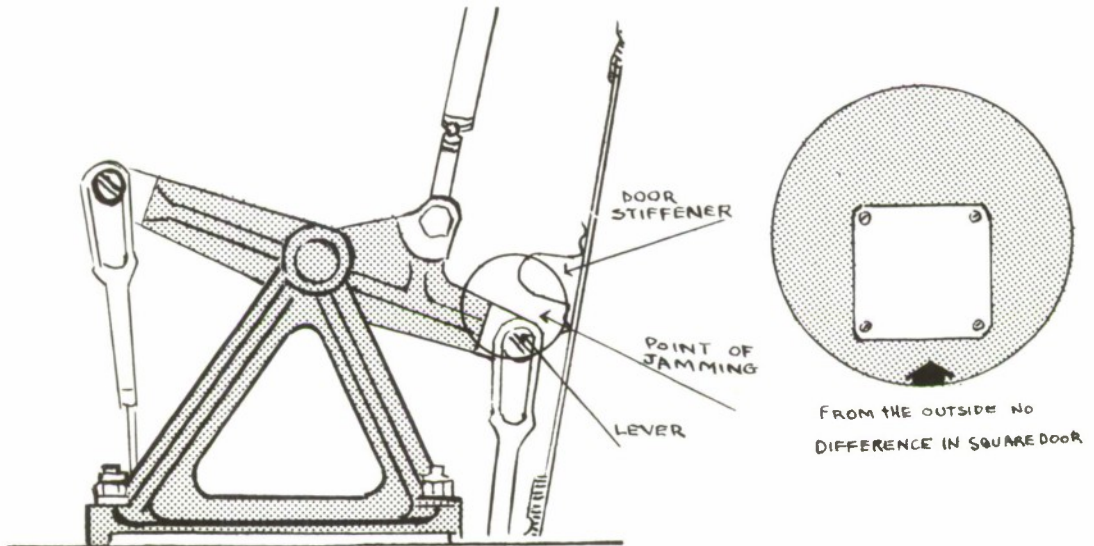


Figure 14

3. GENERAL ACCESSIBILITY

- a. Bulkheads, brackets, or other units should not interfere with removal of units on which work must be done at the line level.
- b. Provisions should be made for easy passage of replacement cables with their attached connectors through walls and bulkheads.
- c. Equipment servicing provisions should be accessible and servicing points identified. (For specific provisions, refer to MIL-S-8512).

4. ACCESS PLATES SHOULD BE EASILY REMOVABLE AND CLEARLY LABELED.

- a. For opening or closing accesses, use fasteners requiring no tools and only a fraction of a turn or snap action to operate.
 - (1) Provide captive fasteners for one-hand operation to avoid loss of fasteners.
 - (2) Use screws only when plate must withstand stress, using a few large screws rather than many small ones.
 - (3) When thumb operated quick release fasteners are used, the operating surfaces should be large enough (at least 1" diameter) to reduce possibility of injury or discomfort.

b. Label all accesses fully, listing items which are accessible through the access, auxiliary equipment to be used, and some symbol to avoid confusion with other accesses. (Also, when applicable, indicate required periods for operations accomplished through the access--such as "Inspect Every 30 Days.")

If not feasible to present required information in 3 to 4 lines on or near access, present in job instructions and identify by the symbol designation labeled on the access.

5. MAKE ACCESSES LARGE ENOUGH FOR EASY PASSAGE OF COMPONENTS, TOOLS AND TECHNICIANS' ARMS AND HANDS.

a. The designer will know the size of components and tools to be used at or inserted through a particular access. He will also know which body members of the technician will be involved. On the basis of such information, size of access can be determined.

b. If technician will be wearing cold weather gear, including gloves or mittens, access dimensions must be increased to allow for such additional clothing. See Appendix A for some specific dimensions.

c. The smallest square hole through which the empty hand can be inserted is $3\frac{1}{2}$ " by $3\frac{1}{2}$ ".

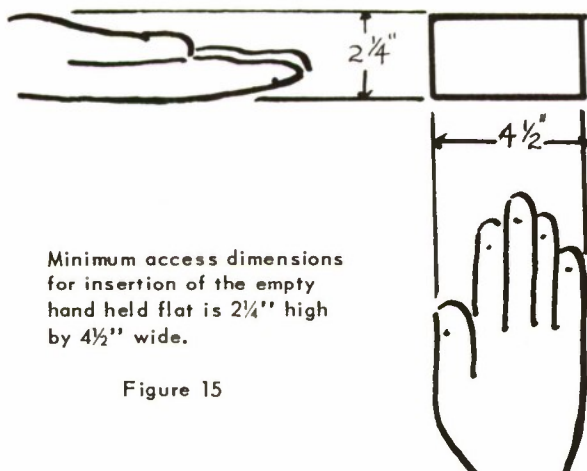
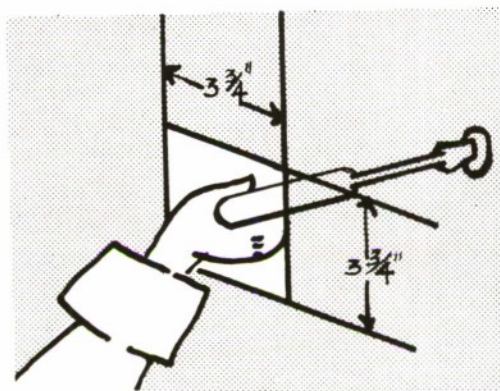


Figure 15



d. For inserting an 8 inch screwdriver with a 1 inch diameter handle, access should be $3\frac{3}{4}$ " by $3\frac{3}{4}$ ". (See Figure 16)

e. Access through which an AN plug with outside diameter of $1\frac{7}{8}$ inches is tightened or installed should be 4 inches square. (See Figure 17)

f. An access through which a hand held box is inserted should be at least $1\frac{1}{4}$ " wider than the box. (See Figure 18)

g. Make access $19\frac{1}{2}$ inches wide if operator must reach into it a full arm's length (to the shoulder). (See Figure 19)

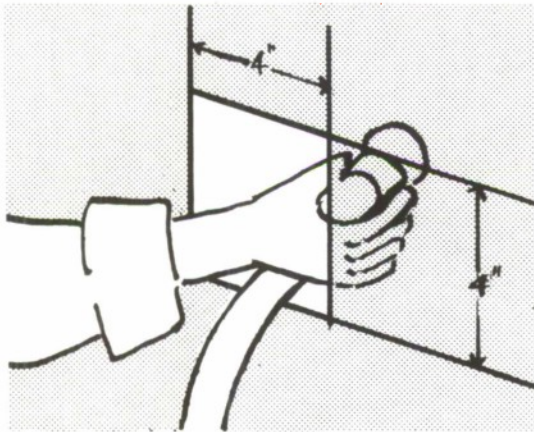


Figure 17

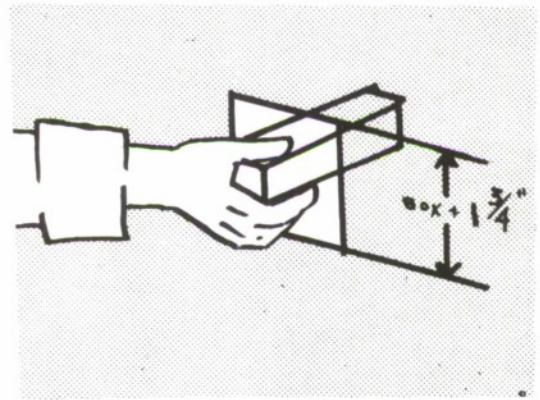


Figure 18

h. If operator must reach through the access a depth of from 6 inches to 25 inches, make the height of the access 4 inches and the width three-fourths of depth reach. (See Figure 20)

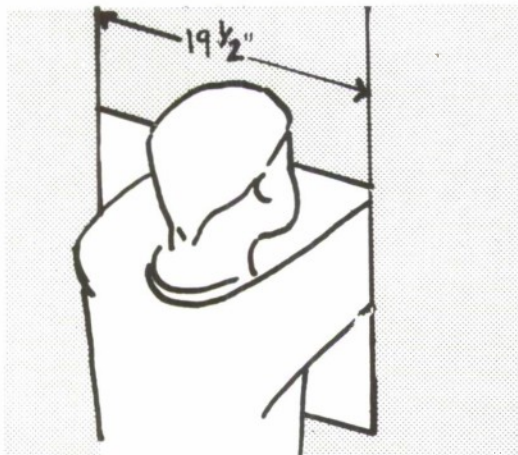


Figure 19

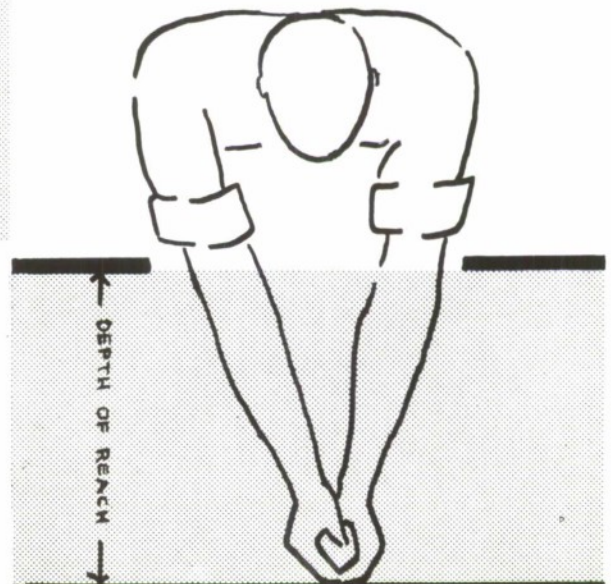


Figure 20

- i. Allow $\frac{1}{2}$ inch on each side of a box to be inserted by handles through an access.
- j. If a box wider than 15 inches is grasped by the sides with two hands and is to be inserted through an access, width of access should be width of the box, plus $4\frac{1}{2}$ inches.

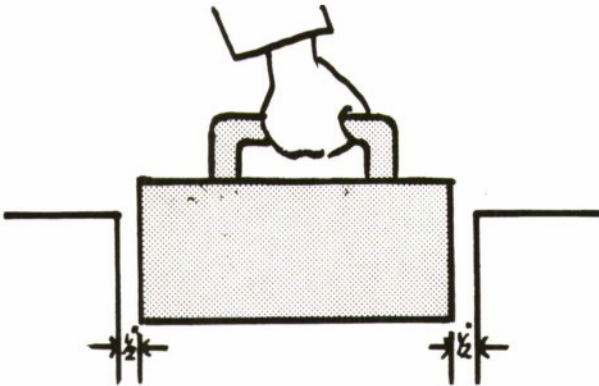


Figure 21

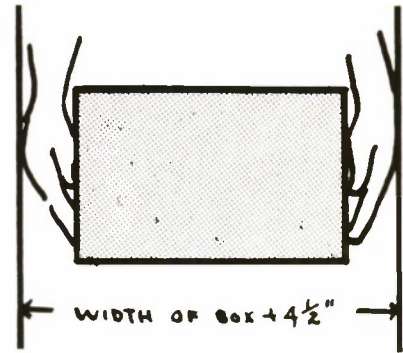


Figure 22

DOORS AND ESCAPE HATCHES

6. DOORS SHOULD BE DESIGNED TO LATCH SECURELY SO THAT VIBRATION WILL NOT OPEN THEM.

A positive locking mechanism should be provided to hold doors open when they are to be kept open.

7. DOORS SHOULD BE OF SUFFICIENT SIZE TO ACCOMMODATE NOT ONLY THE LARGEST INDIVIDUALS TO USE THEM, BUT ALSO ANY EQUIPMENT WHICH MAY LOGICALLY BE EXPECTED TO BE CARRIED THROUGH THEM.

a. When door must be reached by steps or ladder, provide a platform upon which operator may stand while opening door, and offset platform so that operator may stand on it while opening door.

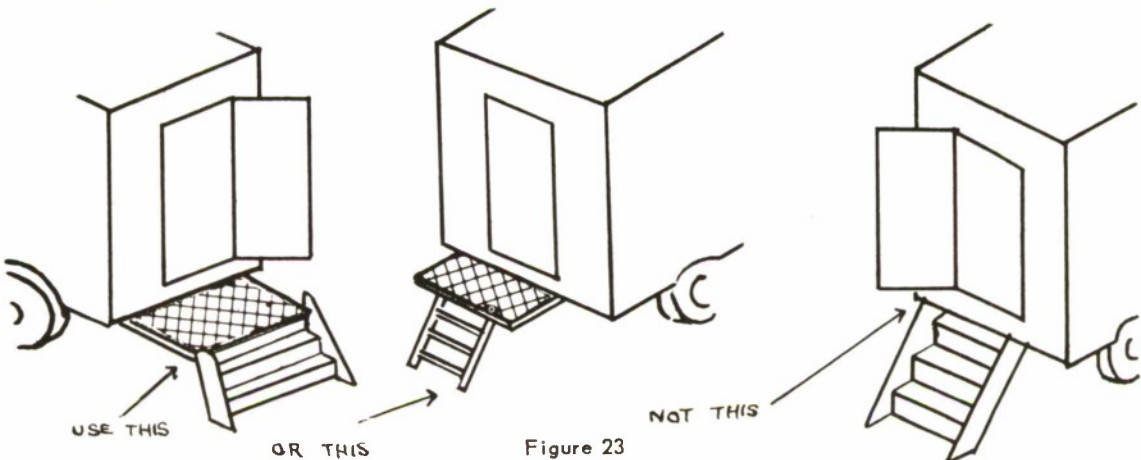


Figure 23



b. Platforms and steps should be made of expanded metal to prevent snow, ice, and mud collecting, with consequent personnel hazards.

8. ESCAPE HATCHES SHOULD BE PROVIDED FOR PERSONNEL IF THERE IS ANY CHANCE THAT THEY WILL NOT BE ABLE TO REACH DOOR IN EMERGENCY.

a. Ordinarily if a large van type trailer has only one door, an escape hatch is required.

b. Escape hatches should be large enough to accommodate largest individual dressed in bulky clothing. (See Figure 24).

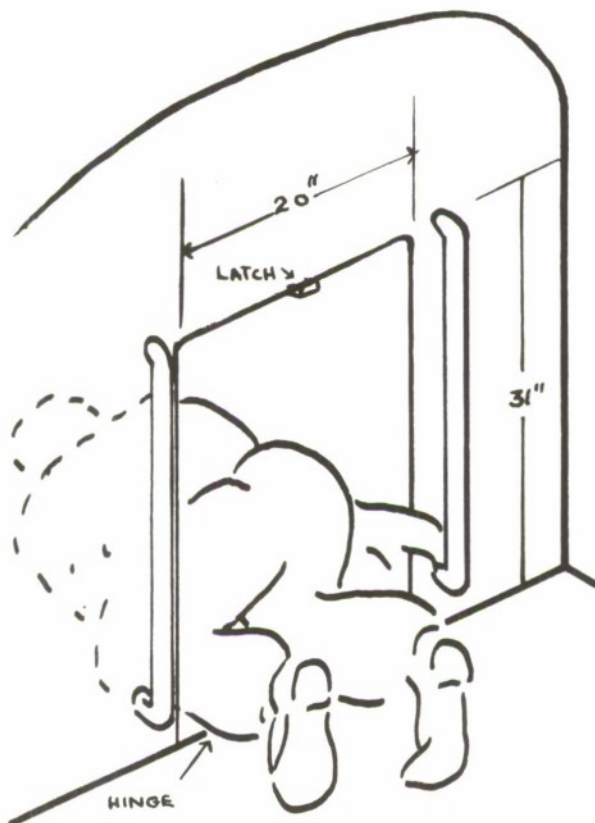


Figure 24

c. Place hinges at bottom and latch at top. Latch should be easy to operate even with gloved hands, and the door should open outward.

d. Inside face of escape hatch should be perfectly plain, with no handles or other protrusions upon which personnel might injure themselves when escaping.

e. Mount handles on the inside wall, one on each side of the escape hatch opening to give personnel a handhold as they push their bodies through the escape hatch opening.

SECTION C. REPLACEABLE UNITS

On every piece of transporting, positioning, and lifting equipment there are replaceable parts and units of various kinds. These include not only black box units, but also replaceable parts like batteries, spark plugs, pins, caps, and covers. Replaceable components should be designed so they cannot be installed in the wrong way. If two parts are physically interchangeable they must also be functionally interchangeable.

REMOVING REPLACEABLE ITEMS

1. ARRANGE REPLACEABLE UNITS IN THE STRUCTURE IN SUCH A WAY THAT REMOVAL IS NOT HINDERED.

- a. Do not require the opening of more than one access panel to remove any single unit.
- b. Arrange components so that units can be removed along a straight or moderately curved line, rather than through an angle.

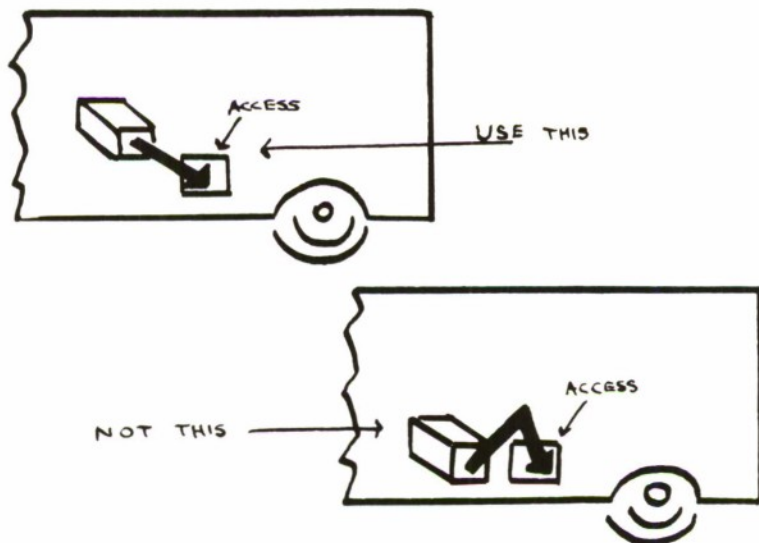


Figure 25

- c. Components should be independently mounted to the housing rather than being attached to each other.
- d. Disassembly of major sub-assemblies or components should not require removal of other components or draining of fuel systems.
- e. Handles and grips should not be in a position where they might catch on other units, wiring, or structural members.
- f. Components should be positioned so that technician does not have to reach too far out for heavy units. Investigation may be required in specific instances to determine optimum placement of units.



g. Placement of removable components should permit technician to stand with his feet a minimum distance from the frontal plane including the grasp axis.

- (1) Maximum lifting force decreases rapidly with increases in this distance.
- (2) Maximum lifting force also decreases with increase of grasp height, but the influence of grasp height is much less than that of foot placement distance.

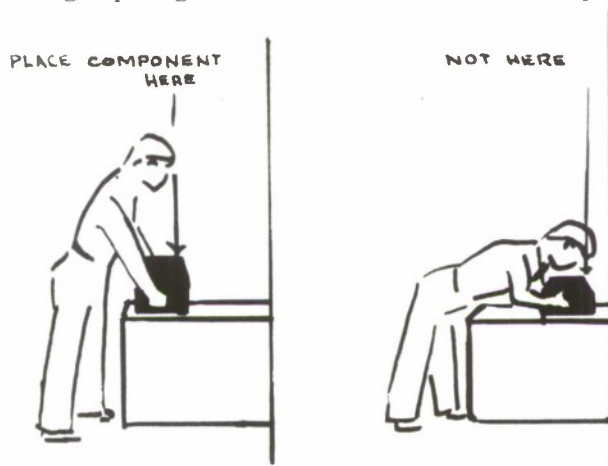


Figure 26

2. DESIGN SURROUNDING STRUCTURE SO THAT REPLACEABLE COMPONENTS CAN BE EASILY REMOVED.

- a. For components which are heavy or relatively inaccessible, provide slide-out racks and hoists to aid in handling. When using roll-out mounting racks, provide limit stops to prevent dropping of equipment.
- b. Use tapered alignment pins, quick disconnect fasteners, and other similar devices to facilitate removal and replacement of components.

3. DESIGN UNITS FOR EASY CONNECTION TO EACH OTHER, BASIC CHASSIS AND HOUSING IN WHICH THEY ARE INSTALLED.

- a. Design units with plug-in rather than solder connection.
 - (1) When using AN connectors, specify quick disconnect type. (See Figure 27)
 - (2) Use connectors requiring no tools (or common hand tools) operating with a fraction of a turn or a quick snap action.
- b. Design mounting bolts, screws, and fasteners so that components can be easily removed with minimum chance for error.
 - (1) Make mounting bolts, screws, and fasteners clearly different from those not used for mounting by embossing the letter "M" on the top of the bolt or screw head, or by making the mounting screws a bright color to differentiate them from other screws.

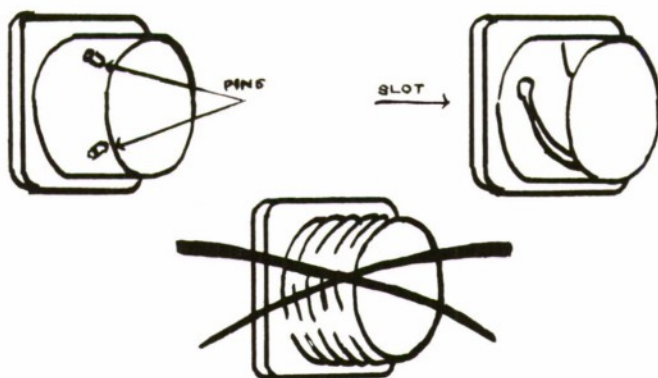


Figure 27: Types of AN Connectors

(2) Keep number of mounting screws to a minimum, consistent with engineering considerations.

(3) If possible, make mounting screws interchangeable for all replaceable units. If screws are not interchangeable, screws with different threads should be of different sizes so they can be clearly differentiated.

c. Bolts with a combination hex head and deep internal slot are recommended as mounting bolts, especially where high torque may be required. If slots become damaged, bolt is jammed, required torque is high, or if a screwdriver is not readily available, a wrench can be used with this type bolt.

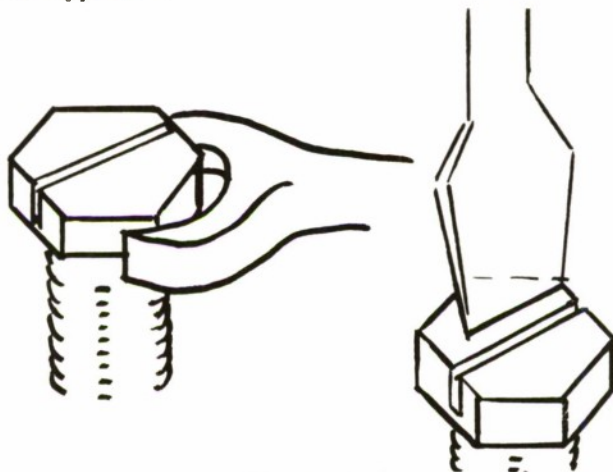


Figure 28

d. Make mounting bolts semi-permanently captive.

e. Minimize the number of turns required to tighten or loosen mounting bolts.

f. When fasteners are used for mounting, specify fasteners which can be operated with the bare hand or at most a common hand tool. *Do not* require safety wiring. Avoid fasteners requiring non-standard tools. Fasteners for assemblies and subassemblies should fasten or unfasten in a maximum of one complete turn.



g. Design mounting brackets and surfaces so that mounting bolts and fasteners are placed on a surface adjacent to the technician's work space.

Provide guides and guide pins for alignment of units on mountings.

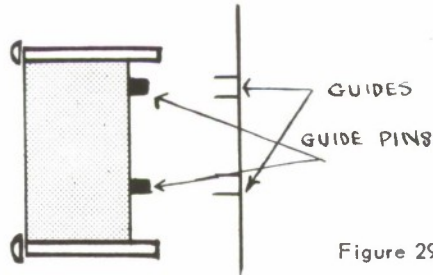


Figure 29

h. When replaceable units have wiring, tubing, or control cable connections, design against the possibility of incorrect assembly.

(1) Make incorrect assembly impossible by using different sizes or completely different type connectors.

(2) Where it is possible to assemble incorrectly, the possibility can be reduced by color coding.

4. DESIGN FOR EASE OF HANDLING REPLACEABLE UNITS AFTER REMOVAL.

a. Keep weight of components under 30 pounds if possible.

b. Provide adequate handles on all units weighing more than 10 pounds and on those weighing less than 10 pounds if they might otherwise be difficult to grasp, remove, or hold.

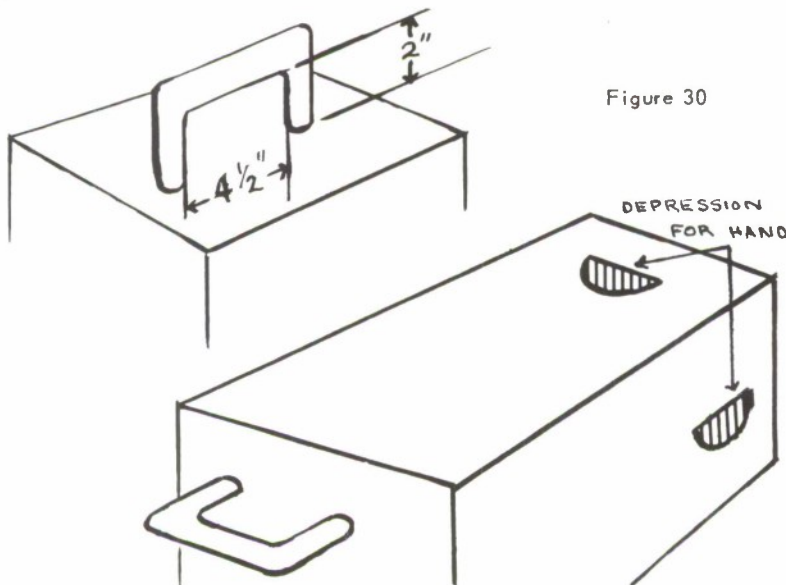


Figure 30

(1) Handles should be at least $4\frac{1}{2}$ inches in length and 2 inches in depth for bare hand. Increase both dimensions at least $\frac{1}{2}$ inch if gloves will be worn.

(2) Place handles above center of gravity.

(3) Heavy units should have recessed handles near the back to facilitate handling.

c. For ease of handling replaceable units after removal, provisions should be made for removing protruding bolts, cables, wave guides, and hoses.

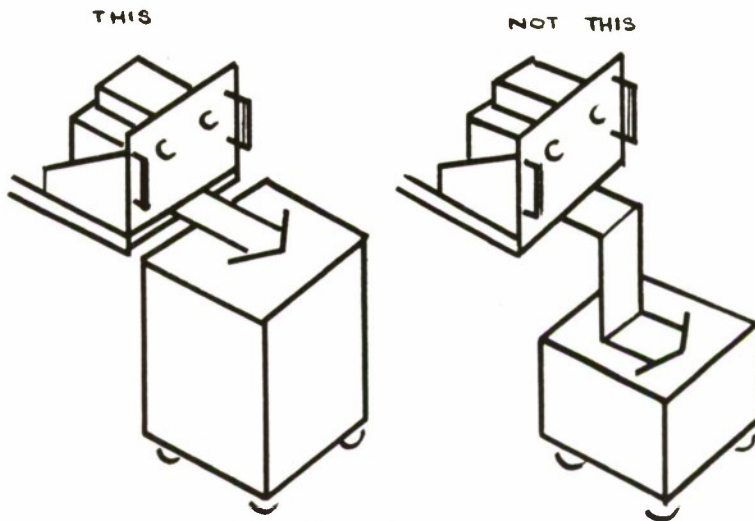


Figure 31

d. Design built-in or auxiliary stands to assist in removing and installing components.

(1) When used to assist in removing or installing components, stands should be of sufficient height to mate with pullout racks.

(2) Stands should be especially designed so that units will not have to be set on delicate components in process of removal or while being worked on.

5. DESIGN FOR REDUCED POSSIBILITY OF LOSING REMOVABLE ITEMS.

a. Attach small removable parts such as pins, caps, and covers to main body of equipment by small chains or other suitable means to prevent their loss.

Do not use bead chains since they tend to break apart no matter how large the beads. Use sash chains or regular link chains. (See Figure 32)

b. Use lock washers or other restraining measures to prevent bolts, nuts, and other components from vibrating loose.

The use of safety wire is not generally recommended, but if it is to be used, provide for means of attaching and make the operation of attaching safety wire as simple as possible.

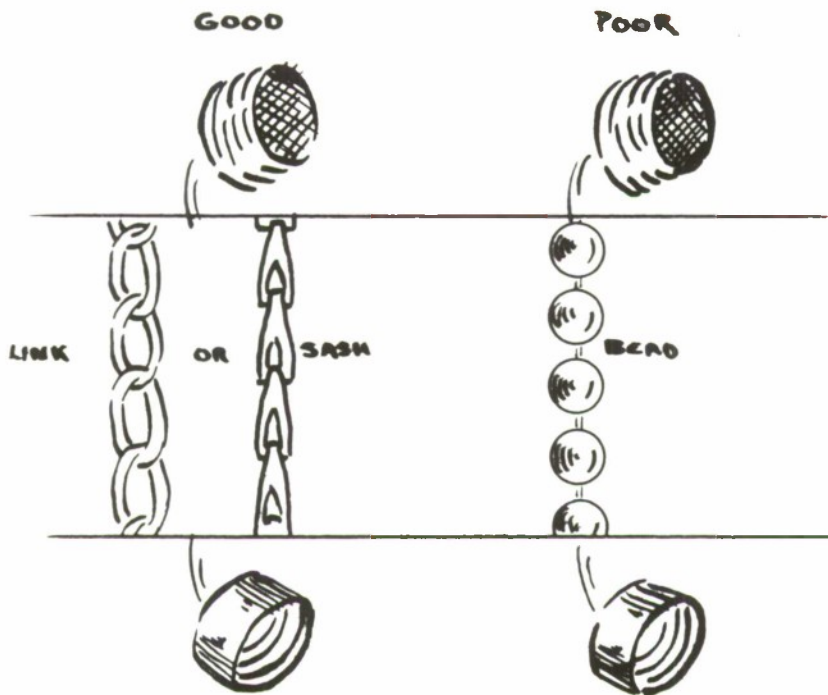


Figure 32

c. Use captive bolts and nuts in situations where the dropping of these small items into the equipment would create a difficult removal problem.

COVERS AND CASES

6. DESIGN COVERS FOR RAPID AND SAFE REMOVAL AND REPLACEMENT.

- a. Provide adequate handles on covers, strong enough to bear the weight of the unit, so that the handles are on top of units when they are being carried.
- b. Covers and cases should have their own stock numbers in the event they must be replaced separately.
- c. Use hinged or tongue and slot catches on covers to minimize the number of fasteners needed.
- d. Covers and cases should have rounded corners and edges for safety.

7. DESIGN UNITS WITH CASES THAT LIFT OFF THE UNIT, RATHER THAN HAVING OPERATORS LIFT UNITS OUT OF CASES.



CHAPTER II

VEHICLES AND MAJOR VEHICLE COMPONENTS

This chapter contains human factors design recommendations for the various vehicles used in transporting, positioning, and lifting bombs, missiles, and rockets. The recommendations contained herein are specific to the particular type of vehicle. Recommendations pertaining to vehicles generally can be found in Chapter I, while Chapter III contains recommendations for design of operator positions.

SECTION A. TRANSPORTING VEHICLES AND COMPONENTS

Included in this Section are recommendations on stores, component, and fueling trailers; tractors and trucks; and major components of these vehicles such as brakes, wheels, casters, and exhausts. Stores trailers are vehicles designed to carry an entire weapon and may include transporters and combination transport-launching vehicles. Component trailers are those designed to carry only a part of the weapon such as a fuse or warhead. They are used both as stands on which to mount the component for servicing and as vehicles to position the component for mating to the main part of the weapon. Although the designer who uses this handbook may never design a tractor or truck, he will find some of the recommendations regarding these vehicles applicable to vehicles which he does design.

STORES TRAILERS

1. Trailers should be equipped with reflectors on all corners for night operations and such reflectors should conform with specifications contained in MIL-M-8090.
2. When the trailer will be used at night, consider providing an extension light or search light, with plug-ins at appropriate positions.
3. If directional arrows are to be painted on the trailer frame, use one of the recommended types indicated in Figure 33.
4. Munitions tie-down facilities should be provided which are readily installed and removed.
 - a. Tie-downs should be equipped with quick disconnect features.
 - b. If tools are required to install or remove tie-downs, they should be common hand tools.
 - c. Avoid turn buckles since their use consumes the most operator time.

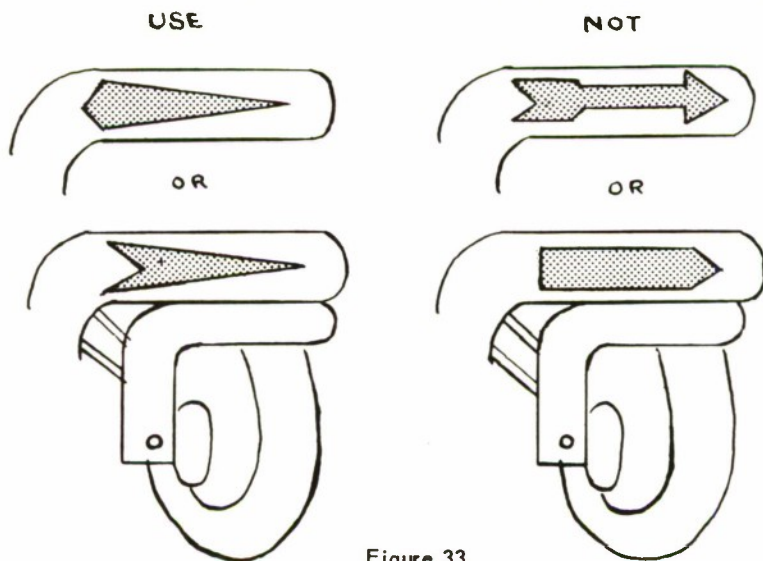


Figure 33



5. Dummy connectors should be provided on the trailer to permit securing of the air hose, electrical cables, etc., when they are not attached to the prime mover.

COMPONENT TRAILERS

6. Design component trailers with precise positioning controls when they are used to mate parts. Do not require operators to manually push or lift the mating components to bring them together.

7. Make the component trailer of sufficient height and configuration so that when it is moved close to the main store, the mating surface of the component on the trailer is directly in line with the mating surface of the main store.

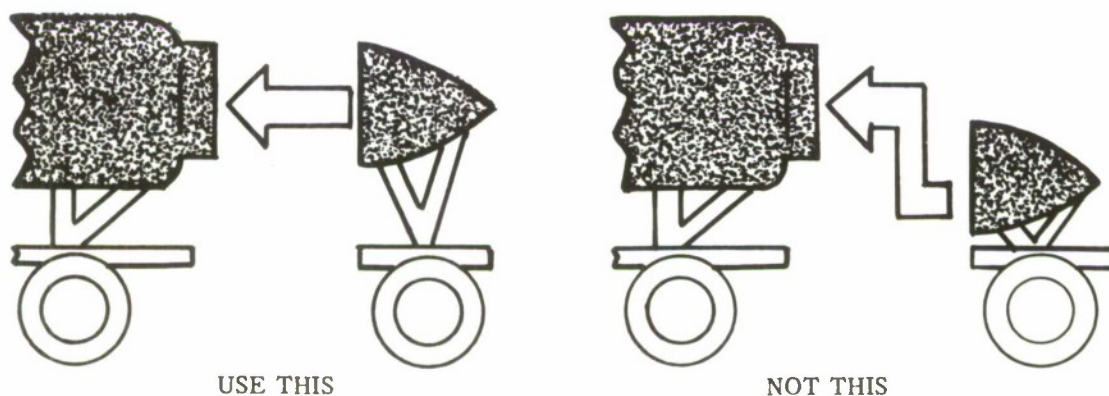


Figure 34

8. If trailer is to be used as a maintenance stand, design into it controls (such as roll and pitch) which will allow technician to position component properly for required maintenance.

• Locate controls on same side of trailer on which technician will be working.

9. Equip trailer with brakes so that when coarse positioning movements have been made by moving the trailer, it can be immobilized for precise positioning with cradle controls.

Locate brake controls so that operator can reach them while restraining the trailer manually.

10. Design into component trailers capability for individual swiveling all four wheels in order to reduce positioning times.

TRUCKS, TRACTORS, AND VAN TRAILERS

11. Truck beds should be of safety-tread type steel or aluminum plate.

If truck beds will be exposed to ice and snow, consider the use of expanded metal for floors.

12. Connections between tractors and trailers should be designed for quick attachment and release and provisions made for tying up connecting lines when trailer is not connected.

13. For large trailers to be attached to tractors, provide landing gear so that trailer can be parked after tractor has been disengaged.

- a. Place landing gear control handle at right side of trailer. Design handle so that it folds when not in use.
- b. Do not require excessive force to operate landing gear handle.
- c. By the use of appropriate materials, labeled warnings, etc., insure that when trailer is painted, moving parts of landing gear will not be painted tight.

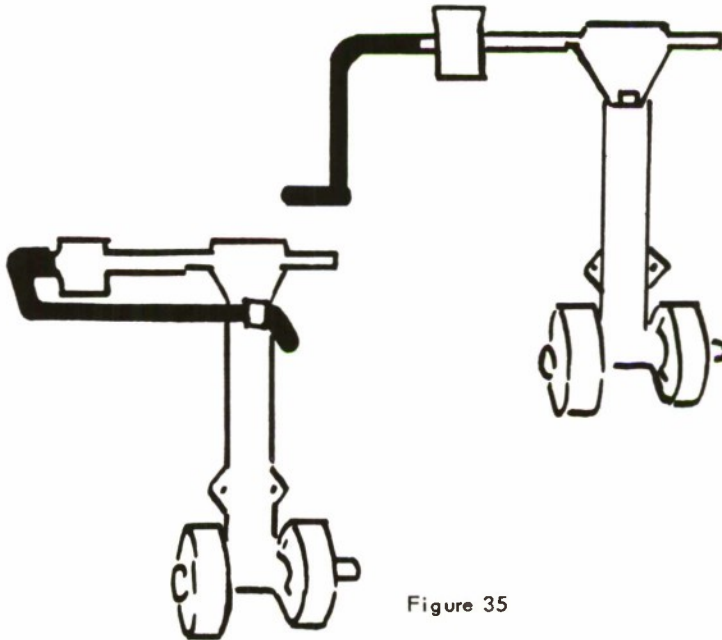


Figure 35

14. Van type trailers may be equipped with skylights in the roof for natural day-light illumination.

Provide sliding type covers for skylight security during night operations.

15. Jacks for leveling trailer (as well as lifting it for tire changes) should be an integral part of the vehicle.

Jacks should have swivel type landing pads.



FUELING TRAILERS

16. Design equipment so that fuel transfer, especially in the case of dangerous fuels, will be as automatic as possible.
17. Design into fueling trailers both auditory and visual warning indicators of dangerous conditions.

BRAKES, WHEELS, CASTERS AND EXHAUSTS

18. PROVIDE ADEQUATE BRAKES FOR NORMAL AND EMERGENCY OPERATION. (See MIL-M-8090)

- a. Where load to be carried is great, consider the use of power assisted brakes.
- b. Trailers which may be used on slopes should be equipped with breakaway brakes for automatic braking in emergency.
- c. If trailer is to be equipped with individual hand operated brakes for each of the four wheels, make the operating levers integral parts of the vehicle, placing them so as to prevent injury to operator.

19. WHEELS AND TIRES SHOULD BE DESIGNED FOR EFFICIENT OPERATION AND EASE OF MAINTENANCE.

- a. Do not require wheels to be removed for minor periodic maintenance such as lubrication.
- b. Design wheel mounting so that wheels can be removed easily and quickly. Avoid the use of guards or panels which might interfere with removal of wheels.
- c. Design storage for spare wheels and tires so that they are accessible regardless of load condition of the vehicle.

20. CASTERS SHOULD BE DESIGNED FOR EASE OF OPERATION AND MAINTENANCE.

- a. Casters should be capable of individual swiveling, swivel locking, and braking.
 - (1) Locking, and unlocking of swivel should not require special tools nor that the operator crawl under the vehicle.
 - (2) Brakes should be foot operated and be an integral part of each caster.
- b. Worn and damaged casters should be easily replaceable.
 - (1) Designer should specify standard off-the-shelf casters wherever possible.
 - (2) Installation of new casters should require only simple tools and low level maintenance abilities.
 - (3) Consider the use of casters with replaceable treads.

21. DESIGN ENGINE EXHAUST PIPES FOR MAXIMUM SAFETY.

- a. Point exhaust pipes of internal combustion engines upward to lessen danger of igniting flammable liquids which may collect on ground or floor.

Use flap type exhaust caps on vertical exhaust pipes.

- b. Shroud exhaust pipes to protect operator from harmful contacts.
- c. Examine necessity to provide cooling for exhaust fumes.
- d. Attach flame arrestors on exhausts used where flammable or explosive vapors and fumes might collect.
- e. Do not permit gases to exhaust into vehicle enclosures.
- f. Avoid placing fuel, hydraulic, or any other lines containing flammable fluid near hot exhaust pipes.
- g. Do not place fabric or insulating material susceptible to oil soaking adjacent to exhaust pipes.
- h. Locate exhaust pipes in such a way that they can be easily inspected for leaks without necessity of removing other components.



SECTION B. LIFTING EQUIPMENT

HOISTS AND HOIST BEAMS

1. LIFTING CONTROLS SHOULD BE INCORPORATED INTO A PORTABLE, LIGHT WEIGHT HAND-HELD CONTROL BOX SINCE ORDINARILY HOIST OPERATORS MUST MOVE TO DIFFERENT POSITIONS AS WEAPON IS RAISED.

a. Provide two spring loaded, recessed push buttons on the control box, one above the other.

(1) The UP button should be on top and the DOWN button should be at the bottom.

(2) If buttons are to be colored, use Green for the UP button and red for the DOWN.

(3) Label control buttons with the words UP and DOWN. Label should be embossed on center of button and there should be an identical label above each button.

(4) Design push buttons with flat (or slightly concave) surfaces and large enough to be repeatedly pushed without discomfort.

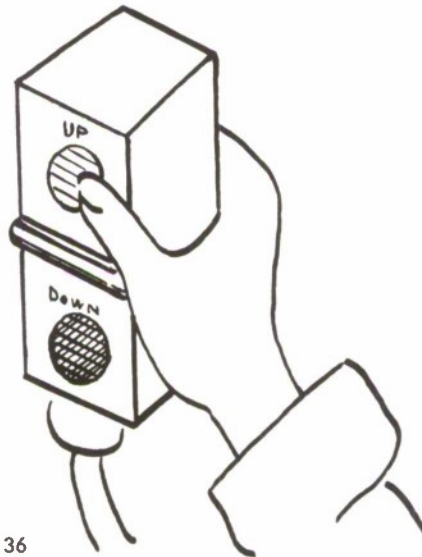


Figure 36

(5) Push button pressure should be 10 to 40 ounces.

(6) Allow two inches between UP and DOWN buttons. To further prevent inadvertent activation of the wrong button, provide ridging between the buttons.

(7) To further differentiate the two buttons for blind operations, texture the one button differently from the other button.

b. Design control box for easy portability, operator comfort, and efficient operation.

(1) Make control box small enough so that operator can reach both control buttons while holding the box securely and comfortably.

(2) Control box itself should be painted a neutral color.

(3) Cables should enter at the bottom of the control box.

(4) Consider attaching strap to control box to prevent dropping and to permit operator use of both hands in other tasks. Strap may also be used for hanging controls up when not in use.

c. In designing controls for hoists where final lifting movements are not critical, lever type controls should be specified where possible.

When lever type controls are used, movement of the control UP should raise the load and movement DOWN should lower it.

2. HOIST BEAM SCALES FOR INDICATING POSITION OF BEAMS FORE AND AFT SHOULD BE READABLE AND EASILY SET.

a. In designing scales, use only as many scale divisions as are necessary.

b. Space scale divisions far enough apart to be distinguished from a distance of at least 28 inches. Minimum separation is 0.05 inch, but this should be at least doubled if conditions permit.

c. Scale numbering should increase from aft to fore and movement of the scale forward should indicate beam movement in the same direction.

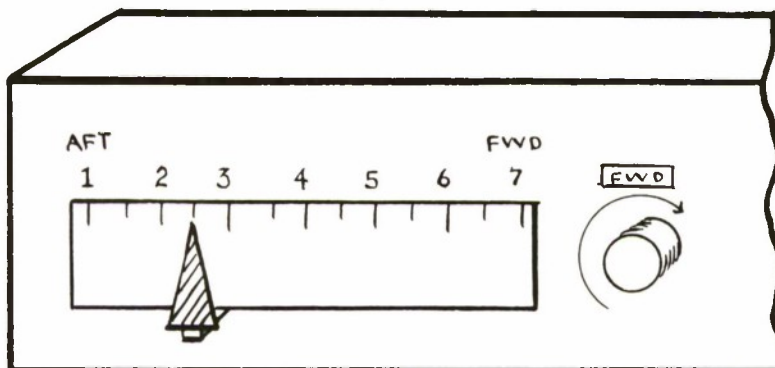


Figure 37

d. If controls for setting scales are mounted on the hoist beam, place them in the same plane as the scales.

(1) Clockwise movement of the control should move the pointer forward; counter clockwise movement should move it aft.

(2) Place a label above the control indicating direction of movement and relationship to scales.



e. Consider the possibility of placing controls for scales on the separate control box.

If controls are mounted on separate control box, place controls yielding fore movement on top and controls yielding aft movement below them.

f. If scale control must be placed on the end of the beam, provide that clockwise rotation will move the beam forward, and counter clockwise rotation will move it aft.

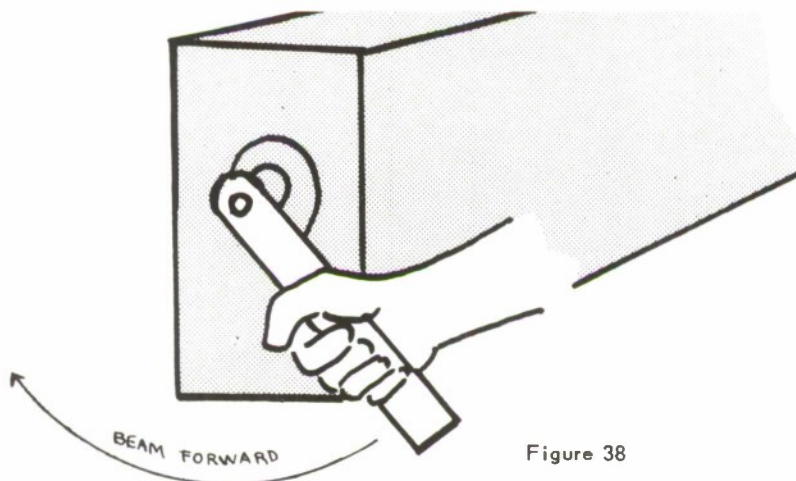


Figure 38

g. Specify ratio of control to pointer or beam movement such that operator will be able to determine immediately if he is moving control in the wrong direction.

3. LIFTING LUGS.

a. For lugs which are used for attaching hoist beams to aircraft structure provide sufficient clearance so that attachment can be made easily and quickly. Use pins which have automatic locking features and do not require insertion of cotter type pins for locking. The pins should be attached to the hoist beams by a wire or chain. Assuming that beams are inspected before being brought to aircraft, this will insure that pins are always available.

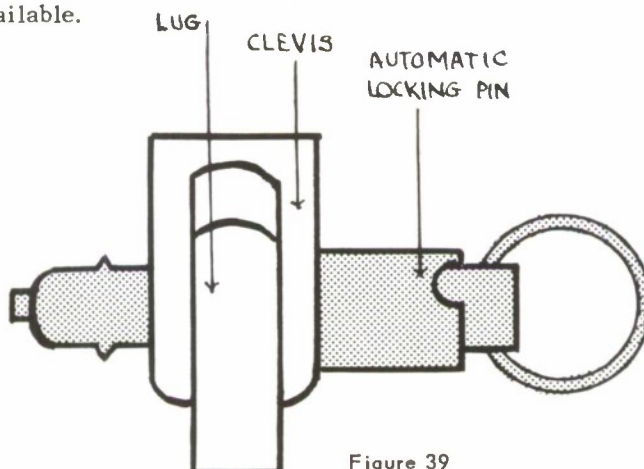


Figure 39

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- b. For attaching hoist beams to weapon or cradle, design matching lugs so that beam lugs can be set into matching lugs and beam will not have to be held in place while pins are being inserted.

4. JUNCTION BOXES.

- a. Junction boxes for hoists should be weather resistant and water tight. Circuit breakers should be recessed push buttons with an indicator light that is ON when circuit breaker is in.
- b. When system requires two junction boxes, they should both be enclosed in the same case.

5. GENERAL CONSIDERATIONS.

- a. To prevent overloading of hoists, indicate capacity in pounds on the side of hoist that will be toward operator.
- b. Make hoist beams as light as possible.
- c. When hoist beams must be held in the raised position, provide positive locking devices so that beams will not fall, causing personnel injury or equipment damage.

JACKS, ELEVATORS, AND LIFTS

6. CONTROLS

- a. Lever type controls are preferred for lifting components when possible.
 - If lever or toggle switch type controls are used, upward or forward movement should raise and backward or downward movement should lower the lifting mechanism.
- b. If controls are rotating type, clockwise rotation should raise the jack head and counterclockwise rotation lower it.
- c. Do not use foot controls for lifting mechanisms, since the feet are relatively limited in their ability to select and manipulate controls and it is difficult to make delicate adjustments with foot controls.
- d. Label all controls used with jacks, elevators and lifts as to their direction of movement and their function.
- e. If the lifting mechanism associated with a particular control must move in a direction opposite to that expected, gear ratio should be such that a slight movement of the control produces large movements in the lifting mechanism consistent with sensitivity of control for fine positioning. This will give the operator immediate information that he is or is not moving the control in the proper direction.
- f. Avoid the necessity for duplicate controls, i.e., at base of lift and at lift head.

If duplicate controls are absolutely necessary for successful and efficient completion of the task, design them so that they are identical in position and orientation.



- g. Permit operator of the lifting mechanism to see the load and the area under the lift head or elevator platform at all times.
- h. Placement of controls should eliminate the need for excessive moving about, and should especially avoid operator having to move into hazardous positions, i.e., under the lift head or under the elevator platform.
- i. Place labels on jack drive shafts to indicate direction of crank rotation to raise or lower the unit.

7. HYDRAULIC LIFTS.

- a. One control panel should be provided, containing all controls and instruments necessary for lifting operations.

Group maintenance controls and gages on a separate panel, preferably at a different location.

- b. Lines between the hydraulic pump and cylinder should be contained internally to reduce probability of damage to lines.
- c. Lifting should be continuously and smoothly controlled from the fully lowered to the fully raised position.

8. ELEVATOR PLATFORMS.

- a. Provide guards around elevator or lift platforms. Such guards should consist of two rails, one at 1½ foot and one at 3 foot height.

Where railing is broken for an entrance opening, place a detachable chain across the opening.

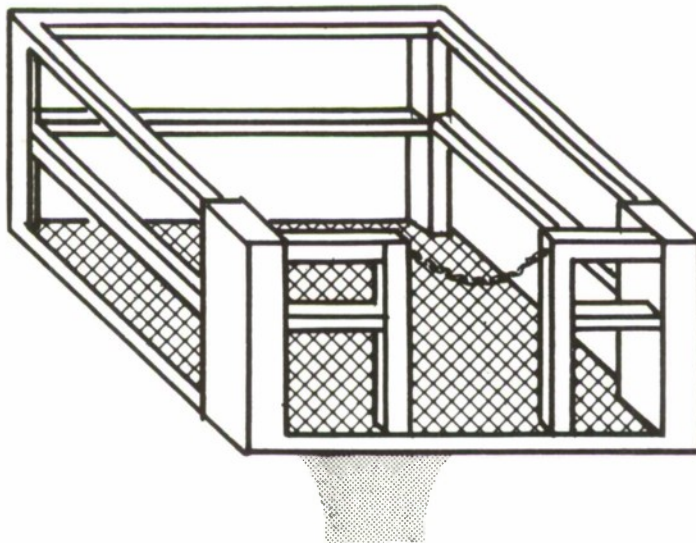


Figure 40

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- b. Design elevator platforms with protective covers (and sides) when they are likely to be exposed to extremes of climate.
 - c. Floors on elevator platforms should be made of expanded metal if there is possibility of ice and snow accumulating on them.

9. SAFETY FEATURES.

- a. To avoid overloading, indicate capacity in pounds on jacks, elevators, and lifts.
- b. Incorporate self-locking, fool-proof devices to prevent accidental or inadvertent collapse of jacks, elevators, and lifts. If possibility for collapse still exists, design features into jacks, elevators, and lifts which permit the device to drop slowly in event of failure.
- c. If lifting mechanisms are fitted with safety features, design them so that they cannot be bypassed or cut out of the system.

CRANES AND SLINGS

- 10. Flood lights should be mounted so that movement of the load carried by a crane can be followed at all times during night operations.
- 11. To prevent overloading, capacity in pounds should be indicated on cranes.
- 12. Identifying and attaching points on slings should be labeled if surface space allows.
- 13. Enclose sling cables in some form of wrapping to prevent injury to personnel and damage to weapon.



SECTION C. CRADLES AND POSITIONING DEVICES

Cradles are structures designed to support a weapon while it is being lifted, positioned, or stored. They may be separate pieces of equipment or integral with transporting, positioning, and lifting equipment. Positioning is usually accomplished by manipulating the vehicle upon which a weapon is loaded. Some equipment, however, such as probes, is designed specifically for weapon positioning.

CRADLES

1. DESIGN CRADLES SO THAT WEAPON CAN BE QUICKLY, EFFICIENTLY, AND SAFELY POSITIONED ON THEM.

- a. When a cradle is designed to carry a particular store, mark guide lines on the weapon so that when store is loaded onto the cradle, perfect positioning will be obtained by merely matching the guide lines.

For visual inspection of proper positioning, place the guide lines on cradle so they will be visible after the weapon is loaded on the cradle.

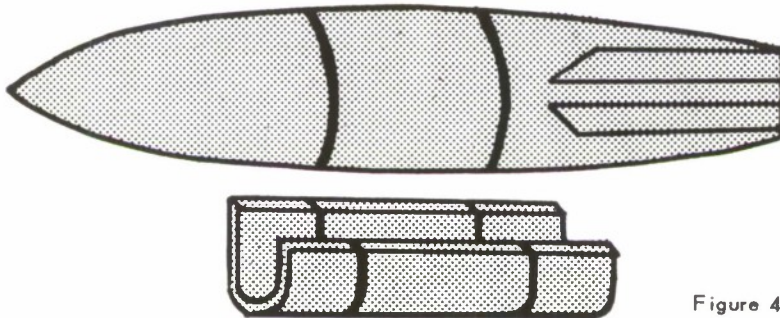


Figure 41

- b. Retaining straps should be equipped with quick-disconnect, easily accessible fasteners.

2. WHEN CRADLES ARE DESIGNED AS INTEGRAL PARTS OF OTHER EQUIPMENT, PROVIDE THE BASIC EQUIPMENT WITH CONTROLS FOR POSITIONING THE CRADLE.

- a. Do not require the operator to reach inside the trailer frame to operate cradle controls.
- b. Design in sufficient cradle travel so that even if basic vehicle is not perfectly positioned, it will still be possible to position the store by means of the cradle controls.

Case In Point

When cradle travel was not sufficient, operators had to position a weapon by pushing and pulling the trailer and in the process not only delayed the operation, but also caused damage to the store.

To assure better initial positioning of the basic vehicle, specify that matching guide marks be placed on the basic vehicle and the aircraft to which the weapon is to be loaded.

c. Design safeguards into equipment with moving cradles, to insure that the cradle in its travel does not cause injury to personnel.

d. In designing movable cradles, make the ratio of control to cradle movement such that operator can tell immediately whether he is moving control in the proper direction.

3. FOR SEPARATE CRADLES WHICH MUST BE ATTACHED TO A TRAILER OR OTHER PIECE OF EQUIPMENT, DESIGN MATING FITTINGS WITH SUFFICIENT TOLERANCE SO THAT ATTACHMENT WILL BE FACILITATED.

a. Secure attaching pins to the cradle with small chains.

b. Color code the matching attaching lugs on the cradle and trailer if there is a possibility of attaching the cradle to the wrong trailer lugs.

c. If different stores are to be used with the same cradle and lifting or hoist points are different, hoist points should be identified for each anticipated store.

POSITIONING DEVICES

4. For positioning weapons under aircraft, a detachable probe (of the plumb bob type) should be designed, to be attached to the structure of the aircraft, at the attaching or contact point. Such a probe would extend down to the weapon and could be lined up with the attaching lug, thrust pin cavity, or other reference point.



CHAPTER III. OPERATOR POSITIONS

This chapter presents human factors recommendations for the design of various operator positions associated with Transporting, Positioning, and Lifting equipment. The following are discussed: (1) Vehicle operator positions, (2) crane operator positions, (3) trailer positions. In addition, a section is included on the seated versus the standing operator. For each of the operator positions discussed, an attempt has been made to include recommendations for every possible set of conditions that might be encountered by the designer. For example, the crane operator for a particular piece of equipment may have only a set of levers to operate, but recommendations are included on foot pedals, toggle switches, hand wheels, and cranks. By including such a wide range of conditions, it is hoped that the design engineer will find answers to most of his human factor problems here, no matter what the configuration of the particular operator position he is designing.

SECTION A. VEHICLE DRIVER POSITIONS

Driver positions are a part of the design of all trucks and prime movers. They are also relevant to those transporting, positioning and lifting vehicles which are self-propelled. Though the positions will range from very simple to quite complex, they will all have seating, display, and control problems. Many will also have windshield design problems.

DESIGN OF SEATS

1. SEAT DIMENSIONS SHOULD PERMIT USE BY A WIDE RANGE OF OPERATORS.

- a. Seat should not be deeper than length of the thigh and should slope backwards 5 to 7 degrees.

A seat depth of 18 to 19 inches is recommended.

- b. Back rests should give support for the whole of the lumbar spine, and should slope backwards (110 to 125 degrees, optimum is 115 degrees).

(1) Recommended height of seat back is 18 to 20 inches.

(2) The seat back should not be less than 21 inches in breadth.

- c. The minimum recommended seat breadth is 19 inches.

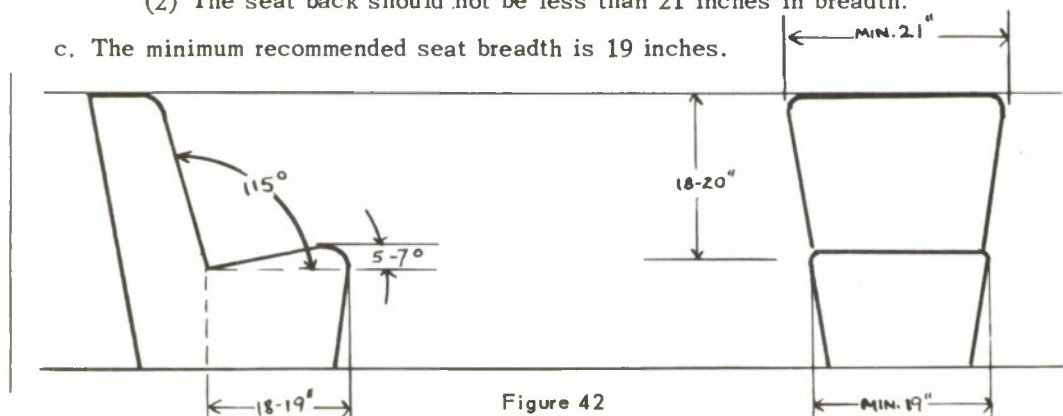


Figure 42

2. SEAT SHOULD BE ADJUSTABLE SO THAT EACH OPERATOR CAN FIT IT TO HIS OWN NEEDS.

- a. Make seats vertically adjustable from a seat height of 14 inches to 19 inches.

A minimum of 4 inches of vertical seat adjustment (in increments of 1 inch or less) should be provided.

- b. Provide a range of 6 inches horizontal (fore-aft) adjustment to permit drivers of various sizes to be equally distant from the controls.

3. SEAT CONSTRUCTION SHOULD BE DESIGNED TO REDUCE VIBRATION AND INCREASE COMFORT.

- a. Do not make seats too soft, but pad seat cushions and backrests to reduce vibration and shock.

- b. All seat cushions should contain two inches of sponge rubber or equivalent.

- c. Seat backs should have a minimum cushioning of 1¼ inch sponge rubber or equivalent.

- d. Seats should be covered with water-resistant material.

Consider the use of porous upholstery or "breathing" fabrics to eliminate annoyance caused by operator perspiring.

4. OPERATOR'S SEAT SHOULD ALLOW OPTIMUM VIEW OF THE LOAD, CRANE EQUIPMENT (IF APPLICABLE), AND SURROUNDING AREA.

DESIGN OF INSTRUMENT PANELS

5. GENERAL CONSIDERATIONS

- a. The instrument panel should be directly in front of the driver, tilted at an angle of 45 degrees from the horizontal. Viewing distance to instruments should not exceed 28 inches.

- b. Arrange dials between eye level and 45 degrees below, with the most important dials at the top left of the panel. Important and frequently used dials should be side by side and near the top of the panel.

- c. Any object requiring binocular visual attention should be within 60 degrees left and right, and 45 degrees up and down from straight ahead point.

- d. Instruments should be separated more horizontally than they are vertically.

- e. If two instruments are so similar in appearance or function that the operator may confuse them, they should be widely separated on the instrument panel unless there are overriding reasons for placing them together.

- f. On instrument dials, correct range of readings should be shown by a green sector on the dial face. If space allows, numbers should be placed outside of scale marks to avoid having the numbers obscured by the pointer. (See Figure 43)

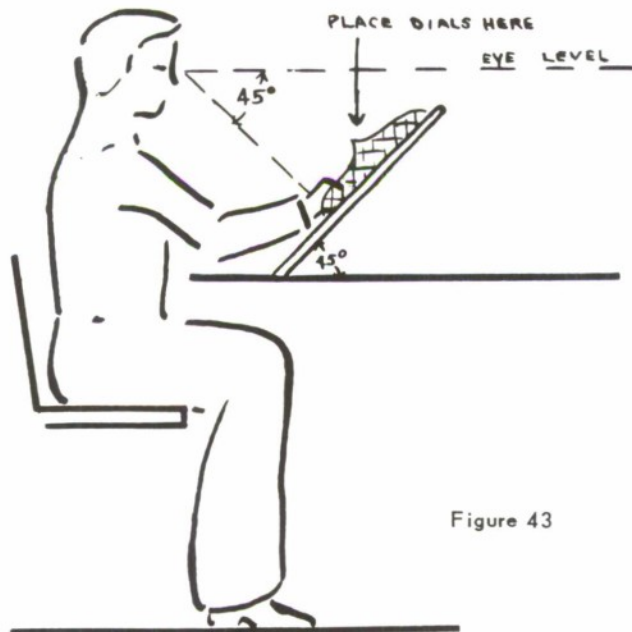


Figure 43

g. Provide warning lights to indicate fire or excessive heat in areas not visible to the operator, Provide indicator warning lights to inform operator of malfunction of components, such as generators, emergency brake position, and engine oil level.

- (1) Use red warning lights for conditions which require immediate action.
- (2) Use amber warning lights for conditions which do not require immediate action.
- (3) Green signal lamps should indicate adequate or satisfactory condition.

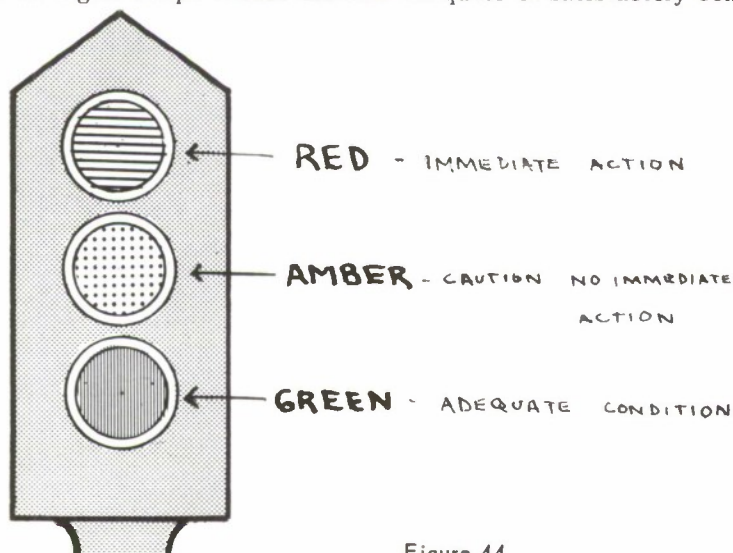


Figure 44

h. When a small number of lights are to be checked on an instrument panel, a square arrangement provides greatest operational accuracy.

i. White faced dials should be used except when dark adaptation is necessary. Sufficient brightness for dial reading is around 0.1 footlamberts.

j. For other than extreme accuracy of reading, the best arc distance between scale marks on a round dial is about one-half inch.

k. Except for such purposes as attracting attention, black letters, numbers, and markings on a white background should be used. Height and width of numerals should be the same. (Height/stroke-width ratio of numerals should be 6 to 1 if reflectively lighted; if transilluminated, the ratio should be about 10 to 1.)

6. DESIGN OF SPECIFIC INSTRUMENTS.

a. Speedometers should be round dials with pointer moving clockwise to increase, total movement a maximum of 180 degrees. Use color on dial to indicate high and low ranges. Locate instrument on panel in such a position that operator can read it regardless of his position or the position of the steering wheel.

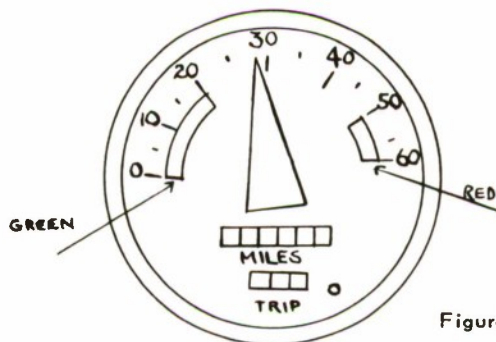


Figure 45

b. When an air pressure gage is required, it should be a round dial. Dial face should contain a red area for low readings. Total amount of pointer movement should be 180 degrees, and clockwise pointer movement should indicate an increase in air pressure. (See Figure 46)

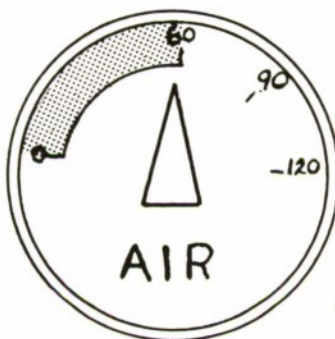


Figure 46



c. The ammeter should be a circular dial. Make pointer move clockwise for increase in charging rate. Total amount of pointer movement should be 180 degrees. Color face of dial so that charge area is in green, discharge area in red. Mount a red warning light immediately above the ammeter to indicate when lit that battery is discharging. (See Figure 47a.)

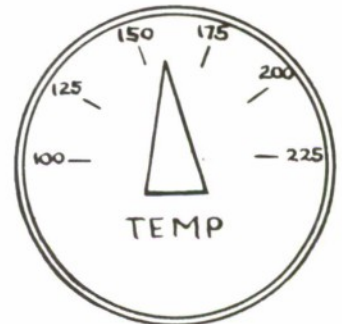
d. For fuel gage provide a rectangular counter, one-half by one inch. Reading on counter at any one time should be in gallons remaining. Zero position of the left counter should be colored red for warning. Downward movement should decrease reading. Place a label below gage reading FUEL-REMAINING. (See Figure 47b.)



a. Ammeter



b. Fuel Gage



c. Temperature Gage

Figure 47

e. Design temperature gage to be circular dial with pointer moving clockwise to indicate increases in temperature. Total amount of pointer movement should be 180 degrees. (See Figure 47c.)

f. If vehicle will be driven under traffic conditions, turn signals are recommended. Panel turn signal lights should be chevron shaped, $\frac{1}{2}$ inch by $\frac{1}{4}$ inch. They should flash at a frequency of 4 flashes per second.

g. When head lights are adjustable, it is recommended that a rectangular ($\frac{3}{8}$ inch \times $\frac{1}{2}$ inch) high beam indicator be mounted on the instrument panel in such a way that it is not obscured by the steering wheel. The word HIGH should be printed on the indicator in transilluminated letters. The indicator should be a steady white light readable only when high beam is on.

DESIGN OF DRIVER CONTROLS

7. GENERAL CONSIDERATIONS

a. Arrangement of controls should permit the operator to maintain his normal posture. His body should be fairly erect at all times.

b. When designing lever type controls, attempt to locate the lever handle or grip between waist and shoulder height. Levers should require a reach of no more than 38 inches for operation. For maximum push on a hand lever, place the lever 29 inches from the backrest for horizontal push.

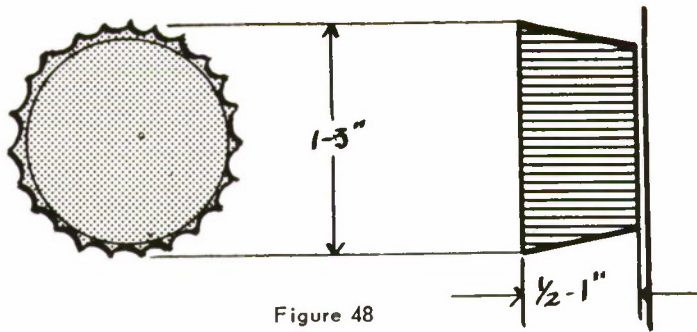


Figure 48

c. Diameter of panel knobs should be between 1 and 3 inches. Small diameter knobs are better for rapid (though perhaps less accurate and less controlled) adjustment than are larger knobs.

d. Knobs which are principally operated by the fingers should not project more than 1 inch nor less than $\frac{1}{2}$ inch from surface of the panel and should be shaped or textured to provide good gripping surfaces.

e. For foot pedal movement the angle of flexion (angle made by thigh and leg) should be 120 degrees for greatest comfort.

f. Pedals on which a large force must be exerted should be located as close to the mid-line of the body as possible. As indicated in Figure 48, as the angle between the legs is increased, the maximum exertable force diminishes.

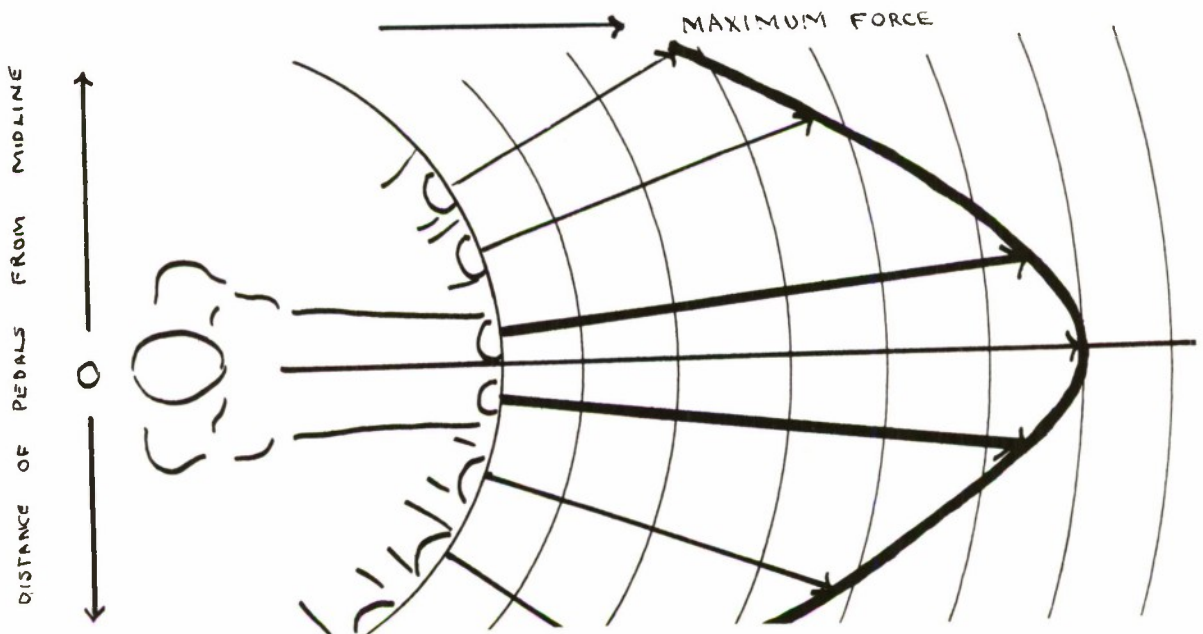


Figure 49



8. SPECIFIC DRIVER CONTROLS.

a. Steering wheel dimensions.

- (1) Steering wheel diameter may vary from 10 to 20 inches and should permit operator to grasp any point along outer rim with either hand. Smaller diameter does not permit smoothness of adjustment but does give faster action. The larger the diameter, the more torque or weight needed to give the steering wheel "feel."
- (2) The underside of the rim should be scalloped or textured to afford gripping surface and prevent hands from slipping along the rim.
- (3) Force required to turn wheel should be about 5 pounds and power steering is recommended.

b. Mounting of Steering Wheel.

- (1) For best efficiency, the driver should hold the steering wheel in such a way that his arm is bent at the elbow by 87 degrees. It is possible to provide this condition by including an adjustment to change the length of steering column.

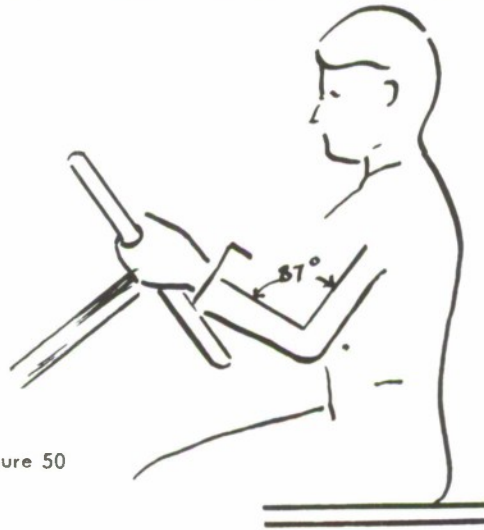


Figure 50

- (2) The recommended angle of steering wheel with the horizontal is 40 to 50 degrees. Greater angles tend to favor taller drivers; smaller angles favor shorter drivers.
 - (3) Steering wheel should be mounted so that its lower edge is a minimum of 24½ inches from the floor of the compartment.
- c. It is recommended that self-cancelling turn signals be provided. The control should be mounted on the left side of the steering column, no more than 2½ inches below the steering wheel. Total amount of movement recommended is 2 inches with a required force of two pounds. Moving the control away from operator indicates right turn; toward operator indicates left turn.

d. For vehicles equipped with standard transmission, locate gear shift lever so that it does not interfere with the operation of other controls. If there is more than one shift lever, separate them and shape code handles to avoid inadvertent activation.

If automatic transmission is incorporated, direction of lever movement should be up and down parallel to steering wheel. Lever gear positions should be identified on a semi-circular plate mounted above the horn.

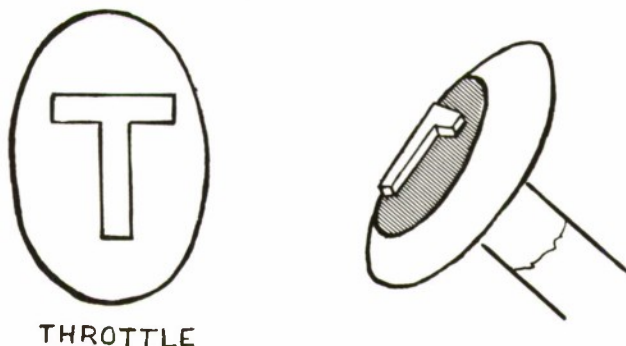


Figure 51

e. Throttle control should be an oval knob designed for finger grip. Control should open with a pull of $2\frac{1}{2}$ inches, close by a quick push. Force required: 2 pounds. There should be a raised "T" on knob and the word THROTTLE on label located beneath control.

f. Design accelerator to be a 5 inch by 12 inch rectangular pedal with rounded corners, having holes for cooling and drying. It should be covered with a non-slip material and should have a curved heel rest. Amount of pedal movement at the tip is recommended to be 4 inches. Force required: 2 to 6 pounds. Accelerator should be separated from brake pedal by at least $2\frac{1}{2}$ inches, and should be as high off the floor (if not higher) than the brake pedal.

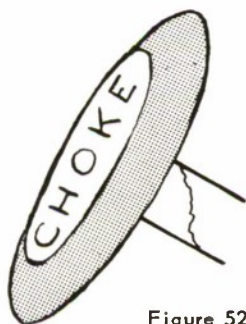


Figure 52

g. Choke should be an oval control, (major dimension horizontal) designed to be grasped by two fingers. It should be mounted near the throttle and should project 1 inch from dash when closed. Control should operate with a pull of two pounds, a distance of $2\frac{1}{2}$ inches from dash, and be equipped with spring return.



h. Service brake should be a rectangular pedal operated by right foot. Distance of travel recommended is 3 inches. Pressure required to actuate brake should be 15 to 35 pounds and there should be sufficient initial resistance so that foot can be rested on pedal without actuating it. Angle of brake with floor should be such that pedal can accommodate the flat portion of the foot. Brake pedals should be capped with non-skid material and should have holes for cooling and drying.

i. Parking brake should be a rectangular pedal, push to set. Amount of movement should be 4 inches, force required: 20 to 30 pounds. Brake should be operated by left toe, released by push on panel control. (See Figure 53a)

Brake release should be a rectangular push to release control. Amount of movement should be $1\frac{1}{2}$ inches, force required: 5 pounds. Control should be red in color with the words "PARKING BRAKE RELEASE" printed in white. Control should be flush with dash when released and should project out when brake is set.

j. Temporary parking brake should be a toggle switch on a mounting plate. Movement should be up for park, down for release. Amount of movement should be 90 degrees, force required: 2 pounds. Control should be labeled as indicated in Figure 53b.



Figure 53a

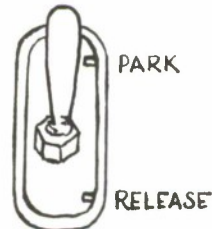


Figure 53b

k. If vehicle has a transfer control, make it an oval knob, (large dimension horizontal). Control should operate as follows: Push for drive, pull for towing and winching. Amount of movement should be $2\frac{1}{2}$ inches, force required: 3 pounds. The word TRANSFER should be embossed on the knob.

l. Include primer pump in winterizing-kit. It should be a round pull and push control. Amount of movement should be 3 inches, force required: 2 pounds.

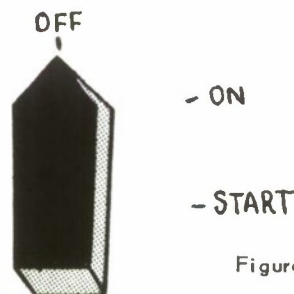


Figure 54

m. Ignition-started control should be rectangular, one end pointed. Direction of movement should be clockwise, amount of movement 45 degrees for ignition only; 90 degrees for start. Force required: 2 pounds. Spring return to ON position after starting.

n. Light switch should be a toggle switch. It should operate as follows: up for head-lights, center for parking, down for off. Amount of movement should be 90 degrees, force required: 2 pounds. There should be a $\frac{1}{4}$ inch round light adjacent to PARKING, which should be on when parking lights are on. Lock should be added if needed.

Dimmer switch should be a button operated by left foot. Should push two inches with a spring return. Force required: 15 pounds.

o. Blackout lights control should be a toggle switch. Direction of motion should be left for OFF, right for BLACKOUTS. Amount of movement 90 degrees, force required: 2 pounds. The words OFF and BLACKOUTS should be on label below.

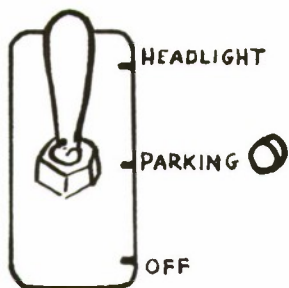


Figure 55a

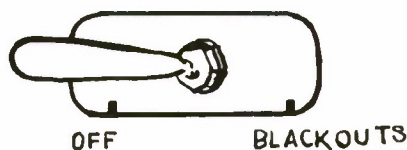


Figure 55b

p. Windshield wiper control should be a pointed knob (like ignition control). Amount of movement should be 90 degrees, force required: 2 pounds. Should provide continuous increase with clockwise movement.

WINDSHIELDS

9. Make windshields rectangular, flat and one piece. Extend windshield from top level of dash to roof of compartment. Corner posts should be as small as structure will permit and windshield should not be curved at edge. Locate top edge of windshield at least 8 degrees above the horizontal line as measured from the eye. Attempt to eliminate center posts, but, if necessary, they should be less than $2\frac{1}{2}$ inches in width.

10. Design windshields of clear glass. Avoid tinted windshields, especially if vehicle is to be used under low illumination conditions or conditions where operator will be required to make important observations in all directions including up.

11. Windshield controls should be of the crank handle type, $\frac{3}{4}$ inches by $3\frac{1}{2}$ inches. They should turn clockwise to raise windshield--360 degree movement should equal 2 inches. Force required: 4 pounds. Controls should be located outside of right corner post and lock should be built into crank handle.

12. Sun visors should be provided for both right and left side of windshield. Visors should be constructed to fit the area they are supposed to shield, and should be designed in such a way that they can be rotated to the side to protect peripheral vision. Consideration should be given to the use of colored transparent sun visors, which reduce extreme glare while allowing some visibility. For safety of operators in case of accidents, edge of visors should be padded. Heavy plexiglass visors are not recommended since they constitute a hazard in case of accident.



13. Windshield wipers should be long and narrow. Wipers should be variable angle, both sides moving in same direction in order to clear the center area of the windshield. (See Figure 56). Electric windshield wipers and windshield washers are recommended.

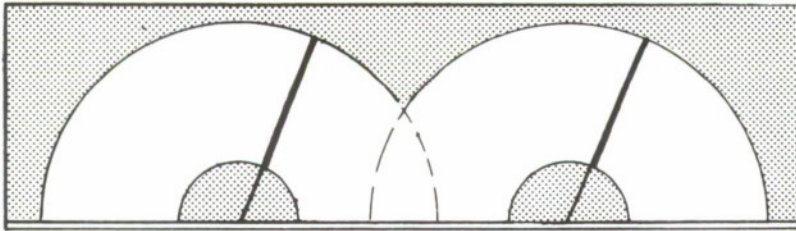


Figure 56. Windshield Wipers

SECTION B: CRANE OPERATOR POSITIONS

1. OPERATOR COMPARTMENT.

- a. Operator's compartment should rotate with crane to allow continuous surveillance of operations.
- b. Design compartment so that operator can see load and areas under the load at all times. Provide operator with devices to warn other personnel of emergency conditions--load swinging, falling, etc.
- c. Place a permanent chart furnishing lifting capacities in operator's cab.
- d. Crane operator compartment should be enclosed if subject to inclement weather.

2. TRUCK MOUNTED CRANES

- a. For truck mounted cranes, it should be possible to apply truck brakes separately during crane operations.
- b. For truck or other vehicle mounted cranes, speed control should be such that operator can move vehicle at a very low speed for positioning prior to lifting.

3. FOOT CONTROLS

- a. Select foot controls for relatively coarse adjustment when operator's hands are otherwise overburdened.
 - (1) Foot controls may be used to effect lateral movement of the load.
 - (2) Limit each foot to no more than two controls.
 - (3) Use feet for controls permitting continuous adjustment. If this is not feasible, specify only one setting position.
- b. Limit forces applied by the operator's feet to 60 pounds.
- c. Space controls far enough apart so that foot gear expected to be worn will clear adjacent controls. Under arctic conditions, larger footgear will be worn.
- d. Keep action simple, positive and free from delicate adjustments in terms of pressure and positioning.

- e. Include non-skid surfaces on foot controls to reduce possibility of foot slipping off.
- f. Controls operated frequently for long periods of time by the feet should be located to the left front or right front of the operator.
- g. Optimum location of footpedals is slightly below seat level at about 70 degrees from the vertical. If high foot pedal force is required, provide operator with a brace at (or above) hip-joint level.

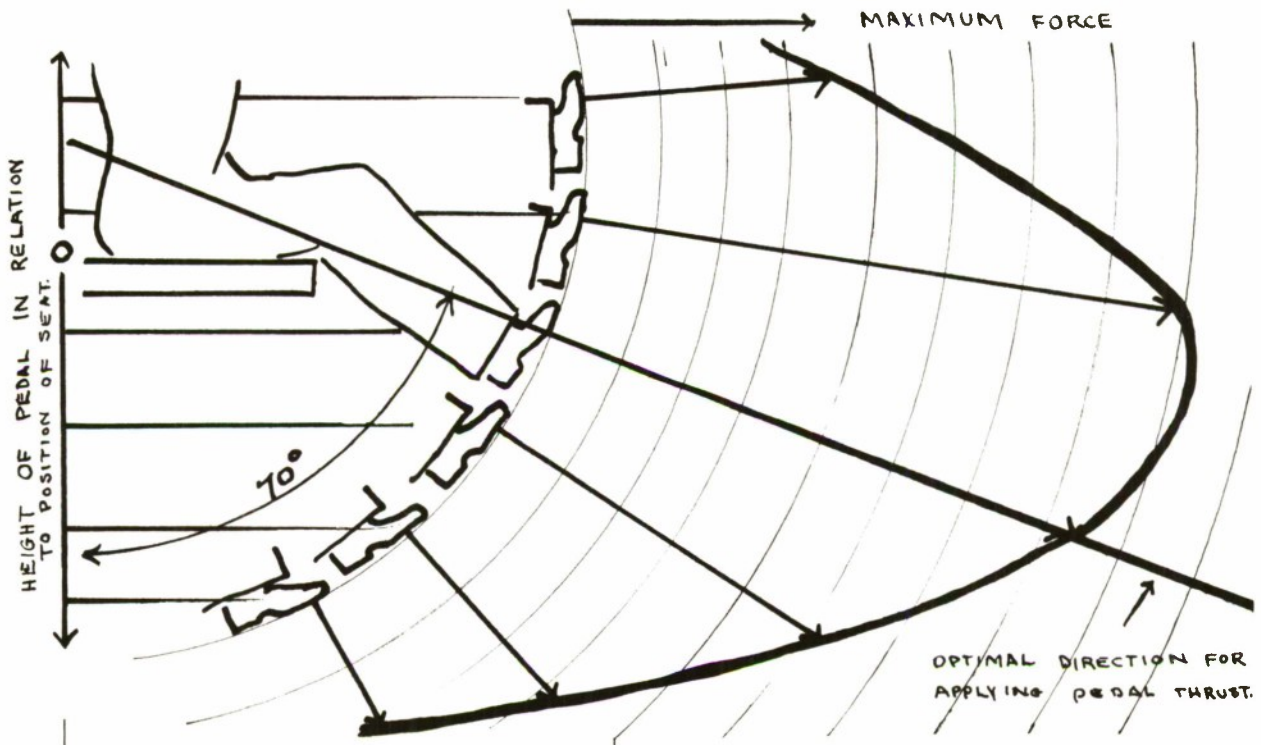


Figure 57

4. GENERAL CONSIDERATIONS IN THE DESIGN OF HAND CONTROLS.

- a. Specify hand controls in preference to foot controls unless there is an overriding reason for the use of foot controls.
- b. Limit forces to be applied by the operator with his hands to 30-40 pounds.
- c. Specify a shape for controls which is comfortable and provides for adequate grasping, taking into consideration the type of gloves the operator may be wearing. Eliminate sharp edges or corners where forceful actions are anticipated. For cold environments, specify materials to which neither the skin nor the clothing will stick on contact. For hot environments, specify materials which tend to minimize this condition and insulate against it.



5. LEVER TYPE CONTROLS

- a. Use lever type controls where relatively large mechanical forces must be overcome directly by action of the control. Levers should be used for lifting components.
- b. Levers should not require a reach of more than 38 inches.
- c. Length of levers (within limits of operator reach) will be determined by the mechanical advantage required.
- d. Maintain a distance between lever handles of 6 to 8 inches to avoid inadvertent operation.
- e. Shape code lever handles (or differentiate them by size), if operator is likely to operate them habitually by touch.
- f. If lever moves from left to right, distance of travel should be no more than 38 inches. More force can be applied moving toward the left with the right hand than by moving toward the right with the right hand.
- g. For fastest operation of a lever in front of the operator have the lever move in a fore-aft direction. More force can be applied by pulling than by pushing.
- h. If lever controls are mounted vertically, place those which yield fore movement on the top and those which yield aft movement below them.
- i. If lever controls must be placed one behind the other, make the control in back higher than the one in front.
- j. For maximum forces, place lever handles at shoulder height for standing operators and at elbow height for seated operators.
- k. For maximum push on a hand lever, place the lever 29 inches from the back seat rest for horizontal push.
- l. When grouped levers in front of the operator pivot about a common axis or relatively close axis, make them move in the fore-aft direction to avoid accidental actuation of levers next to the one being actuated.

6. HAND CRANKS

- a. Use hand cranks for continuous adjustment and where rapid turning is required.
- b. Diameter of cranks may vary from 3 to 9 inches. Optimum diameter for rapid cranking is 4 inches; increasing diameter greatly over 4 inches reduces speed of rotation.
- c. Use two to five pounds load for small high-speed cranks.
- d. Avoid friction when cranks are of light weight and rotating speeds are low.
- e. When cranks are used in positioning elements of the crane, place crank between 36 inches and 48 inches from the floor for standing operator.

f. Cranks should move clockwise for "On, Go, Increase, Up, Travel to Right, Travel Away from Operator."

g. Mount cranks on either side of the frontal work plane in preference to mounting in the center of the operator's body. Locate cranks which must be rapidly turned so that their axes lie within a range from 60 degrees to 90 degrees of the frontal plane of the body.

h. Mount cranks requiring extreme torque so that their turn axis is parallel to the frontal plane of the operator's body.

i. For two cranks rotating simultaneously, place the cranks so that they both rotate in the vertical plane parallel to the frontal plane of the operator.

OR

j. So that the right crank rotates in a vertical plane perpendicular to the frontal body plane and the left crank rotates in the vertical plane parallel to the frontal body plane.

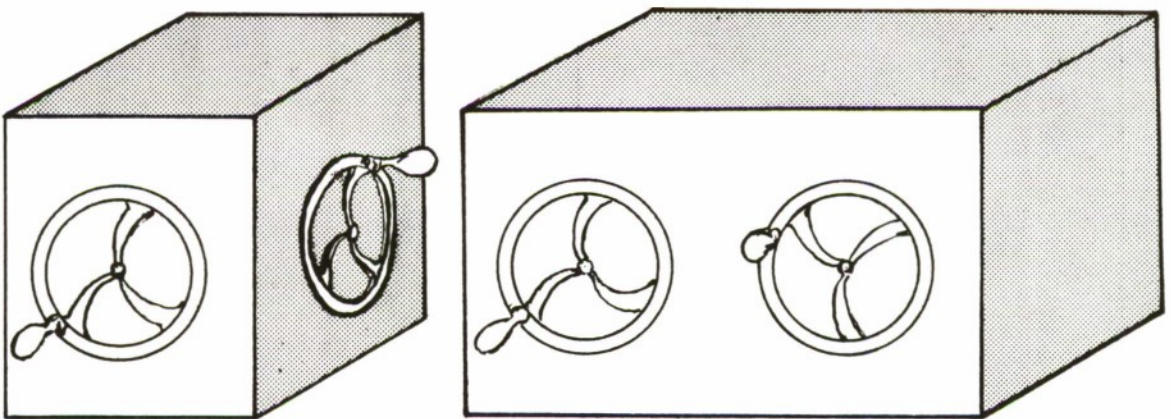


Figure 58

SECTION C: TRAILER POSITIONS

1. PLACE ALL CONTROLS WHICH TRAILER OPERATOR MUST MANIPULATE ON ONE PANEL.

a. Locate control panel so that operator will have an unobstructed view of the entire trailer including load.

b. Vertical location of control panel should not require operator to stoop or reach to manipulate controls.

c. Control panel should be at 90 degrees from the ground, parallel to the frontal plane of the operator.

d. Locate controls according to the sequence in which they will be used or according to similarity of function.



2. CONTROLS WHICH CANNOT BE PLACED ON A SINGLE PANEL SHOULD BE LOCATED WHERE THEY CAN BE OPERATED EFFICIENTLY AND SAFELY.

- a. Place controls so as to eliminate the need for operator to move about excessively.
- b. Location of controls should not require operator to move into hazardous positions, such as under a weapon that is being carried or positioned.
- c. Place controls so that operator does not have to reach inside trailer frame to operate controls.
- d. Do not place any controls where they will require the operator to maintain awkward positions (reaching far up or holding the arm extended) for long periods of time.

3. DESIGN CONTROLS FOR "BLIND" OPERATION SINCE OPERATOR WILL OFTEN HAVE TO BE WATCHING OTHER THINGS WHILE HE IS OPERATING CONTROLS.

SECTION D. SEATED VERSUS STANDING OPERATOR

1. SITTING POSITIONS

- a. Place work surfaces to be used by seated operators 29 inches above the floor.
- b. The recommended angle for tilted *working* surfaces is 60 degrees.
- c. Recommended seat height is 18 inches above the floor.

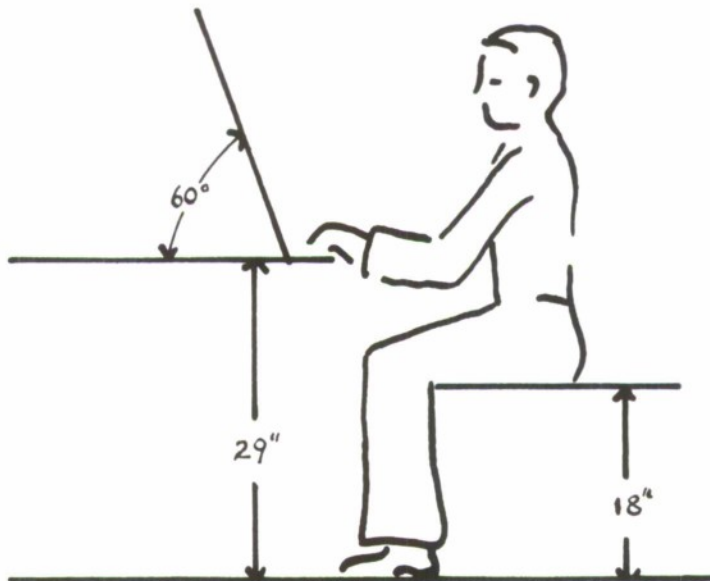


Figure 59

- d. For a task requiring two-hand pull or push, provide the operator with a back rest.
- e. Do not place controls beyond the reach limits of either hand. Approximate reach limits for the seated operator are shown in Figure 60 below.

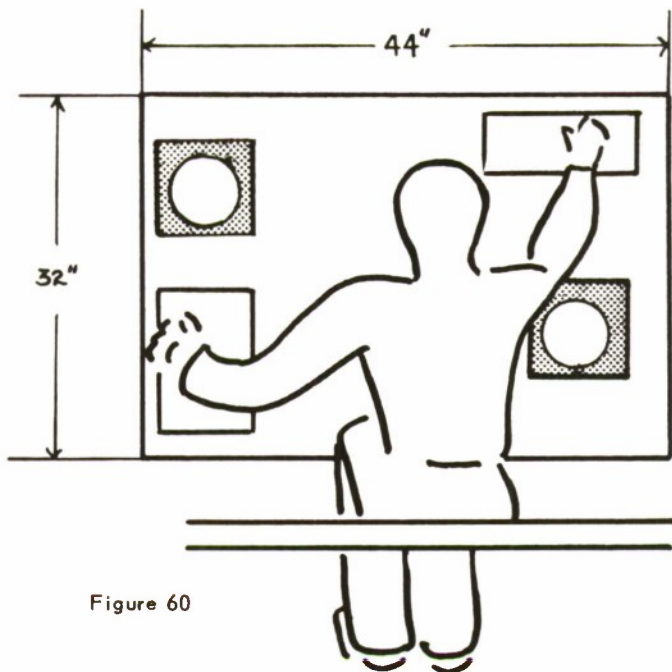


Figure 60

2. STANDING POSITIONS

- a. Work surfaces to be used by standing operators should be located 37 to 41 inches above the floor.

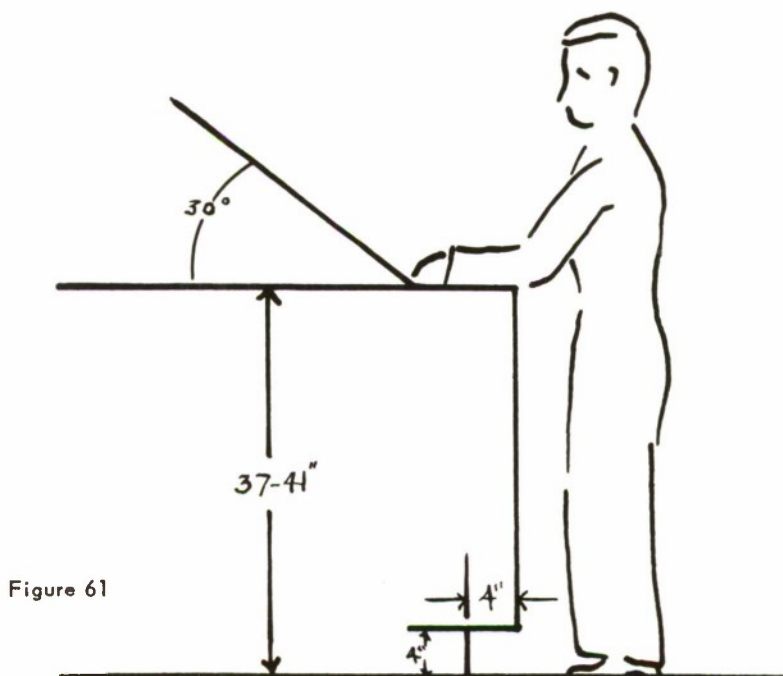


Figure 61



- b. If work surface is tilted the recommended tilt angle is 30 degrees.
- c. If equipment does not naturally provide space for the feet, design kickroom having dimensions of 4 inches by 4 inches minimum.
- d. If operator must stand in one position and operate controls with both hands, do not place any controls beyond the reach limits of either hand. Reach limits for the standing operator are shown in Figure 62.

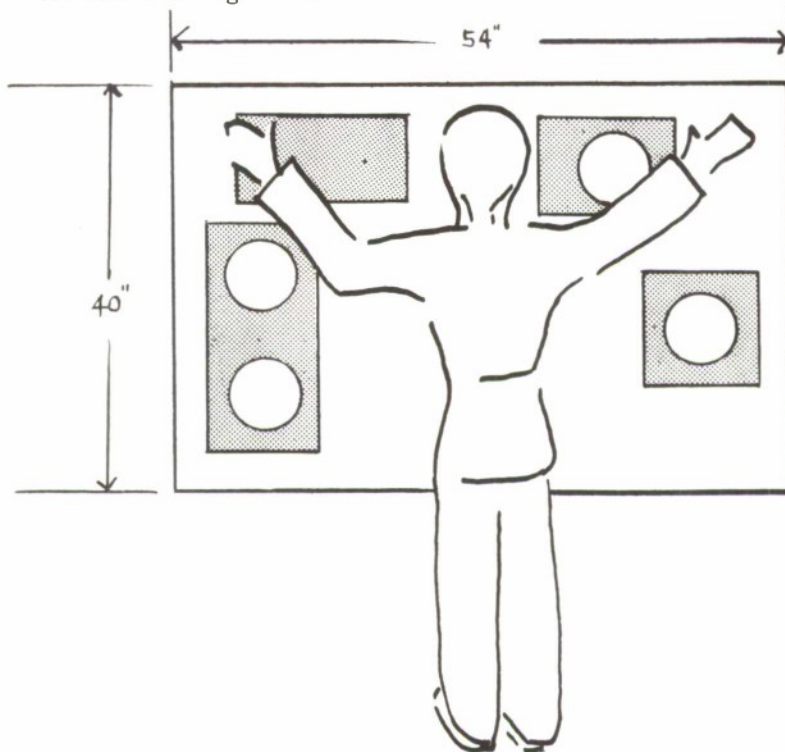


Figure 62

3. COMBINATION STANDING-SITTING POSITIONS

- a. Most transporting, positioning, and lifting equipment will be designed so that the operator will either sit or stand. In some cases, however, equipment may be designed to be operated with the technician sometimes standing and at other times sitting.
- b. When operator alternates between seated and standing positions, a raised seat should be provided. Seat pan should be 34 inches above the floor level and should be adjustable ± 3 inches. The seat should be easily movable into and out of position.
- c. The work surface should be 37 to 41 inches above the floor.
- d. For tilted work surfaces the optimum angle is 45 degrees.
- e. Operator should be provided with a foot rest approximately 16 inches above the floor.

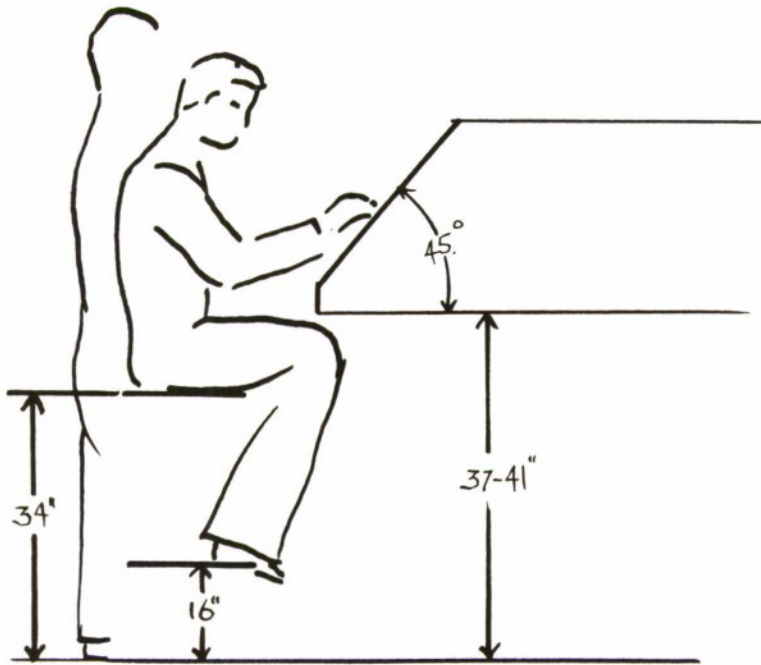


Figure 63 Dimensions for sit-stand position.

f. Avoid the use of pedals if the operator will be free to sit or stand. If pedals are necessary, two sets should be provided, one for the seated position and one for the standing position.



CHAPTER IV. WORK SPACES

For most transporting, positioning, and lifting equipment, work space is a fairly minor design problem. However, on equipment where the operator has a compartment or operates the equipment from a seated position, considerations of proper space, comfort, and efficiency are present. Even when equipment is not characterized by operator compartments or seating requirements, proper lighting, sufficient working space, and safety considerations must be taken into account.

SECTION A. DIMENSIONS AND LAYOUT OF WORKSPACES

Workspaces should be designed and laid out so that operators working in them will be comfortable, able to move body members to the necessary extent, and will have sufficient room to perform required operations.

1. DESIGN OPERATOR POSITIONS FOR EASY AND EFFICIENT ACCESSIBILITY.

- a. Provide large enough openings for entering and leaving work places, using maximum body dimensions as given in Appendix A.
- b. When an operator must climb upon transporting and positioning equipment in the course of doing his work, provide steps and hand grips to facilitate his rapid and safe movement.
 - (1) Hand grips should be at least $4\frac{1}{2}$ inches long and should have a depth of at least 2 inches.
 - (2) Hand grips which are recessed should also conform to the above dimensions.
 - (3) Steps or toe holes should be 3 to 6 inches deep and at least 5 inches wide to accommodate all sizes of foot wear.
 - (4) Recessed toe holes should be at least 4 inches high.
- c. If an operator must move from one position to another in the work place, provide a direct and non-hazardous course for him.
 - (1) Avoid a tendency toward cluttering the work place. Provide a place for every component that may be removed from equipment.
 - (2) Use colored markings on the floor of work places to indicate dangerous areas.

2. ALLOW ROOM FOR NECESSARY OPERATOR MOVEMENTS.

- a. Provide sufficient work space to insure unhampered performance of activities.
 - (1) Allow sufficient space for use of test probes, soldering irons, and other *required* tools without difficulty.

(2) When the arm and hand must be moved from one place to another to perform a task, place the two targets (controls, tools, etc.) about four to eight inches apart.

- b. Design workspaces so that in normal operations, the operator will *not* be required to alternate between two different tasks in rapid succession.
- c. Design space so that the operator can conveniently change his posture and so that he can use his larger body members (arms, legs, and trunk) as well as hands and feet.
- d. The principal working area should be approximately at elbow height and close to the body.

When operator will perform straight work on components, distance of the work surface from the floor for various operator positions should be:

Operator standing	- 3 to 5 feet
Operator sitting	
on the floor	- 1 to 3 feet
Operator kneeling	- 2 to 4 feet

SECTION B. OPERATOR COMPARTMENTS

1. SPACE REQUIREMENTS

- a. Keep the space between the driver and the right side of the compartment free of controls to allow a path for escape in emergency situations.
- b. Distance between the floor of the compartment and the bottom of the dash board should be at least 20 inches.
- c. The forward arm reach required of the driver should not exceed 34 to 35 inches.
- d. The most frequently used controls should be nearest the driver.
- e. All hand operated controls should be placed within the normal arm reach of the driver. He should not have to move from the seat back to perform any normal control operations.
- f. All instruments and hand operated controls should be capable of being seen without head movement.
- g. There should be no controls obstructing the vision of the driver through the windshield.
- h. For entering and leaving operator compartments, specify long, bar-type vertical hand grips.
- i. The recommended distance from seat in operator compartments to ceiling of the compartment (measure taken 4" forward from the front of back rest) is 40".

2. COMPARTMENTS WITH STEERING WHEELS

- a. Do not locate pedals close to or under steering wheel shaft.



- b. Recommended distance from top of foot pedals to lower edge of steering wheel--minimum of 26".
- c. Recommended distance from lower edge of steering wheel to seat back a minimum of 15" in a horizontal line between the rearmost edge of steering wheel (at the midpoint of fore and aft seat adjustability).
- d. There should be a minimum of 10 inches vertical distance between the front edge of the seat and the lower edge of the steering wheel.

3. DESIGN ENCLOSURES AROUND OPERATOR'S POSITION IF THE VEHICLE IS TO BE OPERATED UNDER ADVERSE ENVIRONMENTAL CONDITIONS.

- a. In closed compartments make dimensions of windows large enough to allow escape in emergencies.
- b. If the vehicle is to be operated under arctic conditions, it is imperative that heating and defrosting facilities be provided for the enclosure.
- c. Passenger and driver compartments should be well sealed from the motor and the exhaust system should be made carbon monoxide leak-proof.
- d. Adequate ventilation should be provided in enclosures. Carbon monoxide poisoning becomes a real possibility for occupants of idling trucks in closed cabs within 15 minutes. For maximum comfort, fresh air should be supplied in well diffused manner, at the rate of 35-40 cubic feet per minute per passenger.

Optimal temperature of the air within passenger and driver spaces is 68 to 72 degrees F. with relative humidity between 40 and 60 per cent.

4. AUXILIARY AND SAFETY EQUIPMENT

- a. A cylindrical fire extinguisher should be mounted in a clamp at the driver position. It should be red in color with the word FIRE printed on it in white letters. Force required to pull the fire extinguisher from clamp should be no more than ten pounds and no unlocking should be required to remove it. The extinguisher should be mounted off the floor to allow foot room.
- b. In equipment in which storage space for maps and other small items is needed, a compartment on the right side of the instrument panel is recommended.
 - (1) The compartment should be rectangular in shape.
 - (2) Compartment door should be hinged at the bottom to drop down to the horizontal, and hinges should be strong enough to hold the door when dropped down as a writing area.
 - (3) Inside face of the door should be flat, to provide writing space.
 - (4) Leave the outside face of the compartment door clear for the attachment of instruction plates.

- (5) The button for opening the door should be a spring loaded push button, mounted near the top center of the door. Amount of push button movement recommended to open the door is one-half inch, with a force of two pounds.

SECTION C. ILLUMINATION

The designer of transporting, positioning, and lifting equipment will be directly responsible for work space illumination when illumination is designed into the equipment. He will probably more often be concerned with illumination indirectly: (1) He may recommend to other designers proper illumination for the work places where his equipment will be used, or more likely (2) he will know the range of illumination to be expected and will design his equipment accordingly. Contained in Appendix B is a discussion of terms and units of measurement used in the illumination field.

1. PROVIDE ILLUMINATION ADEQUATE TO ALL CONDITIONS UNDER WHICH EQUIPMENT WILL BE OPERATED.

- a. Design into transporting and positioning equipment lighting fixtures or plugs for extensions so that critical areas may be illuminated during night time operations.
- b. If color coding is to be used, insure that adequate illumination is provided, since at low illumination levels the human eye cannot discriminate colors.

For dark adaptation consider the use of red light of low brightness to illuminate instruments and controls. Avoid color coding under these conditions since colors lose their identity under red light.

- c. For night time operation of equipment where dial reading and comparable visual tasks are involved, brightness values should be at or slightly above 0.05 footlamberts.
- d. For work involving coarse detail (activation of switches, and knobs, reading standard dials, etc.) provide at least 0.01 footlamberts of illumination.
- e. Recommended illumination levels for various tasks are given in Table 1 below.

2. IF IT IS NOT POSSIBLE TO PROVIDE ADEQUATE ILLUMINATION, MODIFY DESIGN OF EQUIPMENT TO TAKE ADVANTAGE OF LIGHT THAT IS AVAILABLE.

- a. If detailed instruction cards attached to equipment have to be referred to under less than three footcandles or through glass protecting the face of the reader, increase the print size to 14 points or more. (Approximately 0.2 inch.)
- b. If illumination will not be sufficient to read dial displays, use flashing lights instead.
- c. Separate physically and shape code controls which operator will have difficulty seeing under conditions of low illumination.



d. Where perception of visual displays is difficult or impossible, consider the use of auditory displays, i.e., convey information by means of sound.

Table 1

RECOMMENDED ILLUMINATION LEVELS

<u>Task</u>	<u>Illumination in Footcandles</u>
Difficult, prolonged tasks with objects of low brightness contrast.	100+
Drafting, watch repairing, inspection of medium materials, detailed drafting, precision machine work.	50+
Sustained reading, object assembly, bench work, general office work.	25+
Occasional reading, power plants, waiting room.	10+
Stairways, supply warehouses. No detailed vision, where some dark adaptation required.	5+

3. DESIGN ILLUMINATION TO AVOID GLARE, REFLECTION FROM WORK SURFACES, AND EYE DISCOMFORT.

- Screen light source from the eyes so that no incident light reaches the reflecting surface.
- Diffuse light by means of light diffusion materials such as opal glass.
- Glass or plastic reflecting surfaces such as dial windows should be glare coated.
- Use dull, dark matte finishes on possible reflecting surfaces.
- Do not overilluminate. Use minimum level of illumination and use several low intensity light sources instead of one high intensity source.
- Place relatively bright light sources outside 60 degrees of central line of vision.

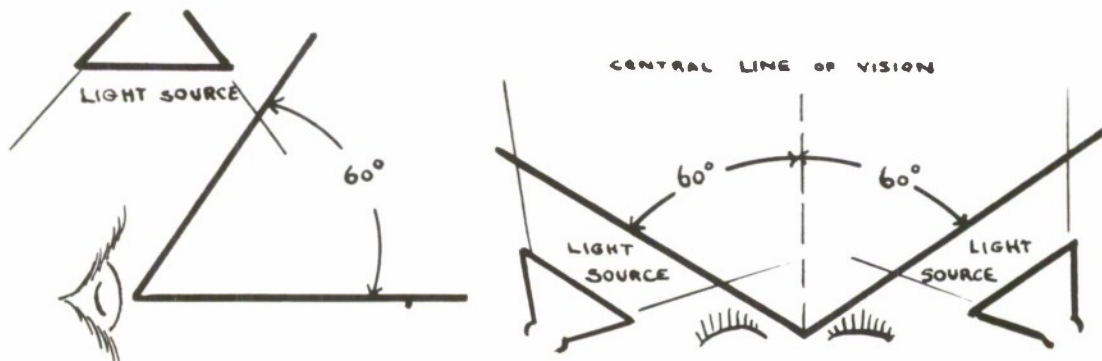


Figure 64

4. CONSIDER THE BRIGHTNESS RATIOS FOR THE VISUAL TASK AREA, IMMEDIATE SURROUNDING AREA, AND GENERAL SURROUNDING AREA.

- a. The area immediately surrounding a visual task area should have a brightness of from one-tenth to the same as the visual task area.
- b. The brightness of the visual task area should be no less than one-tenth nor more than ten times the brightness of any general surrounding area when such area is near the line of sight.

SECTION D. SOUND LEVELS

Sound levels can never be precisely controlled, but the designer should be alert to the elimination of unnecessary sounds. The designer must be concerned with two factors in the control of sound levels. First he must insure that voice communication and auditory signals can be heard. He must also guard against high intensity sounds which might be distracting, uncomfortable, or even physiologically damaging.

1. HUMAN TOLERANCES TO SOUND

- a. At a frequency of 1,000 to 4,000 cps, sound intensity must be between 50 and 80 decibels for comfortable hearing.
- b. In closed operator compartments when noise level is at 65 decibels, oral communication is difficult and at 75 decibels communication is marginal. Table 2 below gives maximum speech interference levels for various distances.

Table 2
MAXIMUM PERMISSIBLE SPEECH INTERFERENCE LEVELS

Distance to the talker (in feet)	<u>Sound Level in db's</u>			
	SHOUT	VERY LOUD	RAISED VOICE	NORMAL
½	90	84	78	72
1	84	78	72	66
2 or more	78	72	66	60

- c. The physiological effect of sound on the human operator depends on the frequency and intensity of the sound, the distance of the operator from the sound source, and the duration of exposure. Physiological damage is a possibility if sound levels in excess of those shown in Table 3 are present in the work space.



Table 3
MAXIMUM SOUND LEVELS TOLERABLE
(in db's - reference 0.0002 dynes/cm²)

Frequency Band in cps	Exposure of Less than One Hour Per Day		Exposure for one to eight hours per day	
	Operator working at or near sound source	Operator at 25' distance from sound source	Operator working at or near sound source	Operator at 25' distance from sound source
35-75	115	100	106	91
75-150	105	90	96	81
150-300	97	82	88	73
300-600	94	79	85	70
600-1200	93	78	84	69
1200-2400	92	77	83	68
2400-4800	91	76	82	67
4800-9600	90	75	81	66

2. CONTROL OF SOUND LEVELS

- For health and comfort of personnel, keep sound levels in work places below 85 decibels.
- Equipment noise level should not exceed the values specified below when measured in a 10 foot radial distance from equipment operating at design capacity:

Frequency (cps)	Sound Level in Decibels
20-75	105
75-150	98
150-300	93
300-600	89
600-1200 and up	85

- Isolate, by soundproofing, sources of noise such as motors and transmissions.
- Dampen or eliminate freely vibrating parts which may raise noise level.
- If equipment must be operated in the presence of excessive noise, specify the use of sound suppressors, ear plugs, or baffles.

3. AUDITORY PRESENTATION OF INFORMATION

- For many types of information (especially warnings), auditory presentation is recommended. Sometimes, however, the noise level in the workplace precludes the use of auditory presentations.

(1) If the noise level will consistently be too high, specify the use of visual displays.

(2) If the noise level may occasionally be excessive, use both visual and auditory displays.

-
- b. Make auditory signals sufficiently different from the background noise so that they may be easily identified.
 - c. Where voice communication is a requirement, provide a 4 to 1 signal to noise ratio.

SECTION E. VIBRATION

1. HIGH FREQUENCY, LOW-AMPLITUDE OSCILLATIONS (VIBRATION) AFFECT EQUIPMENT OPERATORS IN A NUMBER OF WAYS.

- a. Operators report headaches, fatigue, and eye strain.
- b. Depth perception fails with frequencies of 25-40 cps and again between 60 and 90 cps.
- c. Reading speeds are reduced by vertical vibration and increased illumination is necessary.
- d. Operators are more adversely affected by vertical vibration than by horizontal vibration.

2. DESIGN TO REDUCE OR ELIMINATE VIBRATION WHERE POSSIBLE.

- a. Where reading of dials, numerals or printed materials is important, avoid vibrations in excess of .08 mils amplitude.
- b. Vibrations of 10 cps or greater and amplitude of 1/100 to 1/10 cm. should be reduced or eliminated to avoid fatigue, definite unpleasantness, or possible injurious effects.
- c. Avoid vibrations of three to four cps in seats since this is the resonant frequency of the vertical trunk of the human when seated.

Use damping materials and cushioned seats to aid in the reduction of vibration in the operator's body.

- d. Oscillatory motion of driver and passengers can be reduced by lowering center of gravity.

SECTION F. TEMPERATURE, HUMIDITY, AND GASES

1. HUMAN TOLERANCES TO TEMPERATURE AND HUMIDITY.

- a. Temperatures above 75 degrees fall into the discomfort range. The physiologically harmful zone begins at about 105 degrees F.
- b. The scale below indicates the effect on the human body of various temperatures.

- 120° F. Tolerable for about 1 hour, but is far above physical or mental activity range. (160° F. is tolerable for ½ hour).
- 85° F. Mental activities slow down - slow response, errors begin.
- 75° F. Physical fatigue begins.



65° F. Optimum condition.

50° F. Physical stiffness of extremities begins.

c. Discomfort will result if humidity is greater than 70% or less than 30%. Physiologically harmful zone begins at 15% level and grows progressively worse as level is successively lowered.

2. HUMAN TOLERANCES TO GASES.

a. Allowable concentrations of various chemical materials are given in USAF Pamphlet 160-6-1 "Threshold Limit Values for Toxic Chemicals," Shelby Air Force Depot.

b. Discomfort zone is reached at about a 0.01 per cent concentration of carbon monoxide. Level at which physiological damage is a possibility is 0.03%.

c. The carbon dioxide content in an enclosed air space occupied by personnel should not be greater than 0.5%. Between 1 and 2% concentration is not noticeable though it may cut down a person's efficiency. When more than 3% is present, an individual will notice a slight effort in breathing. With between 5 and 10% CO₂ present, person will breathe heavily and tire quickly. More than 10% for any length of time is fatal.

Table 4

NECESSARY VENTILATION RATE

	Oxygen Consumption per Person at Sea Level (cfm)	Ventilation Rate per Person to Maintain Concentration of CO ₂ Below 0.5 per cent (cfm)			
		Sea Level	5,000'	10,000'	15,000'
At rest	0.008	1.2	1.4	1.7	2.1
Moderate Activity	0.028	3.9	4.7	6.7	6.9
Vigorous Activity	0.056	8.7	9.7	11.7	14.5

3. DESIGN RECOMMENDATIONS

a. Design equipment so that chemical materials or substances that exceed threshold limit values when inhaled will not enter work area.

b. When equipment may involve exposure of personnel to dangerous gases, provide warning signals to indicate when dangerous concentration is approached.

c. Provide heating and air conditioning for workplaces and operator compartments if temperature or humidity tolerances are likely to be exceeded under any expected conditions of use.

d. When internal combustion engines are a part of the equipment, insure that exhausts are properly routed to prevent concentrations of carbon monoxide.

e. Provide protective clothing for operators who may come in contact with dangerous chemical materials or substances.

SECTION G. SAFETY IN WORK PLACES

In designing work places for maximum safety, consider all possibilities for personnel injury by fire, explosion, exposure to chemicals, collision, and accidental dropping of weapons, components, or tools. Examine every environmental condition expected and design for safety with repeated use over long periods of time. Make every attempt to eliminate safety hazards, but where potential injury must exist, provide adequate warning placards.

1. PROTECT AGAINST FIRE AND EXPLOSIONS.

- a. Do not permit gasoline tanks to be located within operator compartments, under seat, or immediately behind seat. Vent tanks to the outside of enclosures.
- b. Use spark arresters on equipment incorporating internal combustion engines.
- c. Install fire extinguishers in an accessible location in all work areas where fire is a possibility.

2. PROVIDE SAFEGUARDS AGAINST PERSONNEL INJURY IN CASE OF ACCIDENTAL COLLISION.

- a. In transporting equipment specify seat belts for driver and passengers, especially if vehicle will operate over rough terrain.
- b. Compartment doors on transporting equipment should have safety latches to prevent door opening upon collision.
- c. Design steering wheels to lessen chance of their injuring operator if collision occurs. Specify "deep dish" design whereby the rim of the steering wheel extends a considerable distance beyond the steering wheel column toward the operator.
- d. Seat backs should be anchored to rear of compartment to prevent their moving forward when sudden stops are made.
- e. Possible lethal projectiles in operator compartment should be eliminated.
 - (1) Keep interior of compartment clear of items which might become detached in case of collision.
 - (2) Door handles should point downward or toward front of the compartment.
 - (3) If plastic visors are used, they should be frangible under heavy impact.

3. ELIMINATE DANGER OF CONTACT WITH CORROSIVE AGENTS OR DANGEROUS CHEMICALS.

- a. Avoid use of materials which under certain severe conditions will liberate gases or liquids which are, or may combine with atmosphere to become corrosive, toxic, or combustible.



b. In workplaces where corrosive agents are present, design equipment so that operators need not be physically present by automating equipment to the degree possible - use remote controls, closed circuit venting, automatic closure on pipes and hoses.

c. Do not permit concentration of toxic substances to exceed minimum limits. (See AF Pamphlet 160-6-1)

d. If there is a possibility of contact, design protective clothing for operators who must work in the area.

e. Design detection equipment to warn of dangerous concentrations by means of an auditory signal.

4. DESIGN AGAINST ACCIDENTAL DROPPING OF WEAPONS, COMPONENTS, AND TOOLS.

a. Design into all lifting equipment fail-safe controls that can neither be by-passed nor removed.

b. For all equipment which may be used in situations where there is danger of an accidental drop, attach labels warning of the danger.

c. Provide operators of lifting components a clear view of the load and the area under it. In addition, give such operators control over a warning signal to alert other personnel of an accidental drop.

5. ELIMINATE HAZARDS OF ACCIDENTAL CONTACT WITH HIGH VOLTAGES.

a. Do not permit accidental contact in excess of 40 volts including potentials on charged capacitors.

b. Equip doors, covers, or plates giving access to compartments having high potentials with interlocks which will remove all potential in excess of 150 volts with respect to ground.

Provide protection against bypassing of interlocks by unauthorized personnel.

c. Provide shorting bars that will discharge high voltage capacitors when doors, covers, or plates are opened.



CHAPTER V.

AUXILIARY AND EMERGENCY EQUIPMENT

This chapter is concerned with equipment associated with but not integral to, the prime transporting, positioning, or lifting equipment. Auxiliary equipment includes tools, cables, stands and platforms, tow bars, and spare wheels and tires as well as storage provisions for these items. Emergency equipment is that equipment used in case of fire, explosion, or other accidents.

Both auxiliary and emergency equipment should be readily available, easily recognizable, and easy to use; but should not interfere with normal operations when not in use. The designer must give consideration to the design and location of auxiliary equipment in the early phases of prime equipment design.

1. GENERAL CONSIDERATIONS.

a. Storage space for auxiliary equipment should be accessible under all conditions of equipment configuration.

- (1) Do not require removal of trailer load to gain access to auxiliary equipment.
- (2) Label storage space, indicating auxiliary equipment stored there.
- (3) Do not permit auxiliary equipment to interfere with normal operations when not in use.

b. Attach auxiliary equipment to main equipment where possible.

Do not use bead type chains for attaching. Use sash or regular link chain.

c. Where attaching by chain is not feasible, clamp auxiliary items to main equipment.

Do not require excessive force to remove and do not require special tools.

d. Label auxiliary equipment to identify the main equipment with which it is associated.

e. Use off-the-shelf items for auxiliary equipment whenever possible.

Do not require special tools in using auxiliary equipment.

f. Provide spares for items which may be lost or which can be replaced by operators, such as pins, spark plugs, batteries, etc.

g. For every piece of auxiliary equipment, consider the possibility of making it an integral part of the prime equipment.

2. TOOLS

a. Do not require special tools unless the operation cannot be performed with common tools. Analyze each situation very carefully before specifying special tools.

b. When special tools are required, design each for as many different uses as possible, making sure, however, that tools are compatible with the tasks for which they are designed.

c. Specially designed tools must be compatible with design of the prime equipment on which they will be used.

d. Use hand operated fasteners where feasible rather than requiring any tools.

e. For tools which operator must use with the equipment, provide a tool box permanently attached to the equipment in an accessible position yet not in the way.

(1) Design the tool box specifically for the tools that will be put in it. Insure that it is large enough for all sizes of the same tool that may be supplied.

(2) Provide compartments in the tool box for ease of finding proper tool.

f. Design tools for usability and safety under all environmental conditions expected.

(1) Tool handles should be knurled to provide adequate gripping surfaces.

(2) Tools should be of reasonable weight and bulk, and designed for simplicity and ease of operation.

(3) Provide non-sparking tools for use near explosives and/or flammable material.

(4) Adequately insulate both handles and other parts of tool which technician is likely to touch if tools are to be used near high voltage.

(5) Provide tools with a dull finish so they do not reflect glare in strong sunlight.

3. CABLES

a. When removable cables are included in the design of a piece of equipment, provide storage space for the cables.

b. If cables are not removable, design equipment so that cables are out of the way when not in use.

c. Specify cable connectors requiring no tools, operating with a fraction of a turn or a quick snap action.

d. Provide cables with caps to prevent entrance of dirt and moisture.

4. STANDS, PLATFORMS, AND LADDERS

a. Provide built-in or auxiliary stands so units will not be set on delicate components while being worked on.

b. If stands are an integral part of the equipment, be sure that operator can reach all items he must manipulate without danger of falling off stand.

c. If auxiliary stand is equipped with wheels, brakes should be provided.

d. When ladders are required for climbing upon equipment they should be permanently attached to the equipment where feasible.



- e. Walking surfaces on stands and platforms should be designed for good traction under all weather conditions.

5. TOWBARS AND TRAILER TONGUES.

- a. Design towbars and trailer tongues to be easily stowed when not in use.
 - (1) For towbars and detachable tongues, provide storage space on vehicles.
 - (2) If tongue is not detachable, provide means for stowing it out of the way.
- b. Design towbars and tongues to reduce possibility of injury in case they fall on operator's toes.
- c. Make provisions for quick attachment and detachment of towbars and tongues.
 - (1) Presence of load on vehicle should not unduly hinder attachment.
 - (2) Use quick disconnect pins rather than nuts and bolts.
- d. Keep weight of towbars and tongues as light as possible consistent with stress requirements.

If towbar is necessarily heavy due to the weight of the trailer plus weapon, special design features (extra length, multiple handles) should be incorporated to allow manning by the required number of personnel.
- e. Towbars and tongues should be equipped with clamps for securing air, electric, and hydraulic interconnecting hoses which must be attached to a prime mover during roading operations.
- f. When a towbar is used for steering, provide a tongue extension to facilitate precise positioning if necessary.

6. SPARE WHEELS AND TIRES

- a. Locate storage for spare wheels and tires so they will be accessible whether vehicle is loaded or not.
- b. Insure that location of spare wheel and tire stowage will not interfere with the performance of trailer maintenance.
- c. Position spare tires so that operator will have no difficulty checking tire pressure or performing other periodic preventive maintenance on wheel and tire.

7. EMERGENCY EQUIPMENT

- a. All equipment incorporating internal combustion engines should be provided with a fire extinguisher.
 - (1) Locate fire extinguisher in an accessible location.
 - (2) If fire extinguisher is not constantly visible to operators, provide labels directing attention to its location.
 - (3) Do not locate fire extinguisher where it will interfere with normal operations.

b. Provide first aid kits with those pieces of equipment which will be used at locations remote from medical facilities.

Standard kit may not contain necessary items so it may be necessary to design first aid kit for the particular situation.

c. If equipment is such that personnel are susceptible to unusual or specific kinds of accidents (such as electric shock) instructions for treating such accidents should be labeled at the appropriate location on the equipment.



APPENDIX A

HUMAN BODY MEASUREMENTS (ANTHROPOMETRY)

The engineer needs information on body measurements in the earliest design stages to be sure that the equipment he designs will accommodate operators of the size and shape who will be using it. The purpose of this Appendix is to describe the types of anthropometric measurements available to the designer, to indicate some of the sources of such information, and to give examples of the more common measurements, with cautions as to their use.

TYPES OF BODY MEASUREMENTS

Body measurements may be thought of as being either static or dynamic, both of which are important to the designer. Measurements of stature and of the individual limbs and parts of the body are of the static type. Dynamic measurements are concerned with the range of movements of which the various body members are capable.

Static measurements include everything from measurements of the most gross aspects of body size, such as stature, to measurements of the distance between the pupils of the eyes. Obviously the measurements used will depend on the particular equipment being designed. The more common measurements have received most attention from anthropometrists and are thus the ones which are not only most available, but also the most reliable because of the large and numerous samples on which they have been taken.

The human body when moving is quite different from the body at rest. Dynamic measurements give such information as arcs of travel of various parts of the body, natural movements of body members, and space needed for member travel. Because of the time involved in making such measurements and the complexity of analysis as compared to static measurements, the amount of dynamic measurement data is rather small. A few of the more readily available measurements are given in the last section of this Appendix.

SOURCES AND USE OF INFORMATION ON BODY MEASUREMENTS

The designer has basically two sources of information on body measurements. He can consult anthropometric surveys in which measurements of a sample of the population have been made, or he can perform experiments under circumstances which simulate the conditions for which he is designing. Which of these two procedures, or a combination of them, is followed depends primarily on the availability of adequate anthropometric surveys, but also on time and cost considerations. That is, the designer may be forced to use less than optimum anthropometric data because actual experiments to solve his peculiar problem would cost too much in time and money.

Anthropometric data are usually presented in terms of percentiles, ranges, and means (or medians). With information of this type the designer, who usually will not be able to accommodate all possible sizes, can decide where to make a cutoff. He should of course design equipment so that all members of the population for which it is designed can operate it, but he may have to inflict less efficient or less comfortable operation upon a small percentage of the population. The designer may be able to accommodate perfectly all except

those individuals having extreme measurements and may thus design for those within the 5th and 95th percentile. On the other hand, the equipment may be such that individuals at the lower extremes simply cannot operate it unless it is designed for the 1st percentile. In this case the designer may be forced to accommodate only individuals up to the 90th percentile, with the consequences of inefficient and uncomfortable operation by individuals above the 90th percentile.

At the end of this Appendix is a bibliography of some of the more well known anthropometric studies, both static and dynamic.

EXAMPLES OF BODY MEASUREMENTS

The examples in this section are divided into two parts. Part I contains static body measurements data and Part II contains data on dynamic body measurements.

A few words of caution are appropriate in using these or any other anthropometric data. The designer should evaluate such data in terms of the size of the sample on which measurements were taken and the characteristics of the individuals making up the sample. Obviously measurements of 5000 individuals are more reliable than those of 50, but regardless of sample size, the measurements of a group of basketball players would not be appropriate for use in designing equipment to be used by average military personnel.



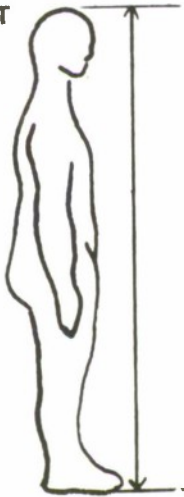
PART I

The measurements given below are weighted averages computed from various anthropometric surveys. The measurements are divided into five groups and for each group the population samples used are given.

As is usually the case in anthropometric surveys, measurements are for nude individuals. Additional allowance must be made for clothing to be worn. Comments are included for each measurement as to how the measurement was taken and, where appropriate, estimates are given for allowances to be made for arctic clothing. See Table A at the end of Part I for estimates of amounts to be added for various types of cold weather clothing.

The following nine dimensions are based on measurements of 2960 Air Force cadets, 103 champion civilian drivers, 271 regular civilian drivers, 2500 Army drivers, and over 4,000 flying personnel.

HEIGHT



Average: 68.85"

95.5% between 63.76" and 73.94"

Add 1.9" for heavy winter clothing.

How measured: Subject stands looking directly forward. A measurement is made of the vertical distance from the floor to the top of the head.

SHOULDER HEIGHT



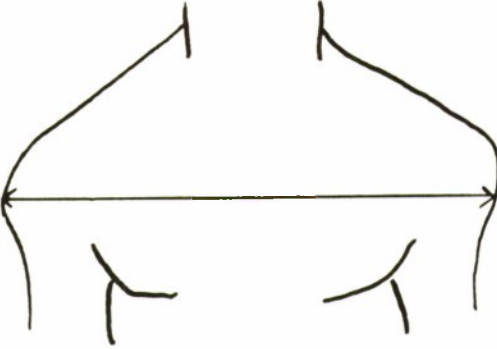
Average: 23.31"

95.5% between 20.91" and 25.71"

Add .6" for heavy winter clothing.

How measured: The subject sits erect. The vertical distance from the sitting surface to the right shoulder is measured.

SHOULDER WIDTH



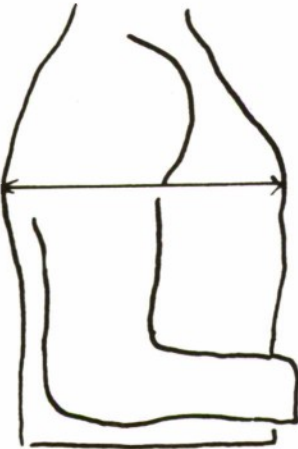
Average. 17.91"

95.5% between 16.13" and 19.69"

Add .7" for heavy winter clothing.

How measured: The subject sits erect, upper arms hanging at his sides and his forearms extended horizontally. The horizontal distance across the maximum lateral protrusion of the deltoid muscles is measured.

CHEST DEPTH



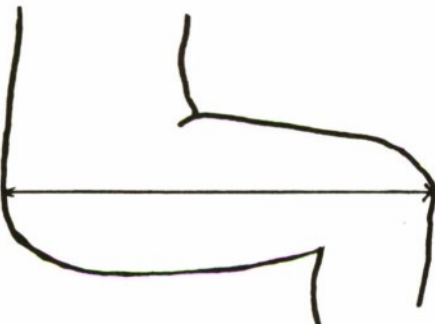
Average: 8.57"

95.5% between 6.77" and 10.37"

Add 1.4" for heavy winter clothing.

How measured: At the level of the nipples, the depth of the chest is measured with an anthropometer contacting the breastbone and the spinal groove.

BUTTOCK KNEE LENGTH



Average: 23.49"

95.5% between 21.29" and 25.69"

Add .5" for heavy winter clothing.

How measured: Subject sits erect. The measure is the horizontal distance from the rearmost point of the buttock to the front of the kneecap.



SEAT BREADTH



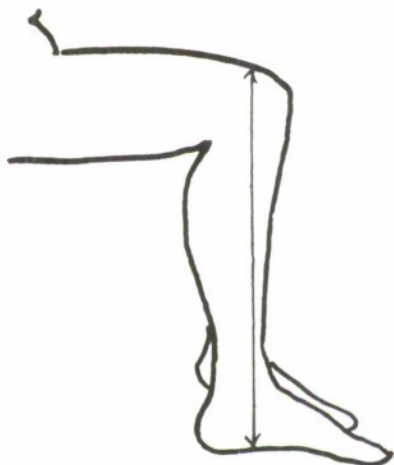
Average: 13.94''

95.5% between 12.12'' and 15.76''

Add 1.3'' for heavy winter clothing.

How measured: Subject sits erect. The measure is taken horizontally across the widest lateral diameter of the buttocks.

KNEE HEIGHT



Average: 21.70''

95.5% between 19.60'' and 23.80''

Add 1'' for ordinary shoes or 1.8'' for heavy winter boots.

How measured: Subject sits erect, feet resting on a surface so that his knees are bent at a right angle. The vertical distance from the surface to the top of the right knee (not the kneecap) is measured.

FOOT BREADTH



Average: 3.85''

95.5% between 3.29'' and 4.41''

Add 1.2'' for heavy winter boots.

How measured: The right foot just touches the side wall and the longitudinal axis is parallel to the wall. The measure is to the widest part of the foot.

FOOT LENGTH



Average: 10.48''

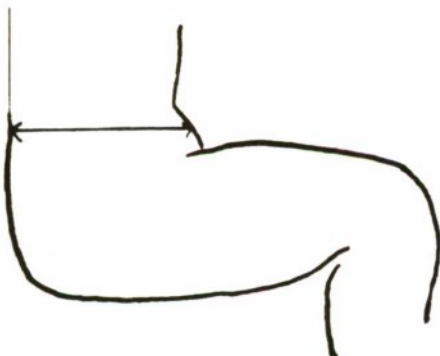
95.5% between 9.51'' and 11.45''

Add 2.7'' for heavy winter boots.

How measured: The right foot is measured from the wall which the heel touches (the longitudinal axis of the foot is parallel to the wall) to the tip of the longest toe.

The following dimension is based on measurements of 2960 Air Force cadets, 103 champion civilian drivers, 271 regular civilian drivers, and 2500 Army drivers.

ABDOMINAL DEPTH



Average: 8.59''

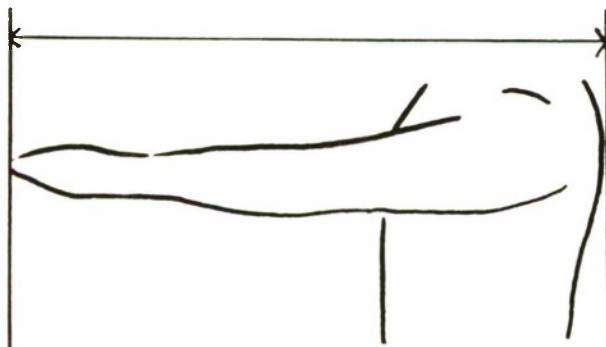
95.5% between 6.80'' and 10.38''

Add 1.4'' for heavy winter clothing.

How measured: This is the maximum horizontal contact dimension in the abdominal area.

The following dimension is based on measurements of 2960 Air Force cadets, 103 champion civilian drivers, 271 regular civilian drivers, and over 4,000 flying personnel.

ANTERIOR ARM REACH



Average : 34.88''

95.5% between 32.49'' and 39.07''

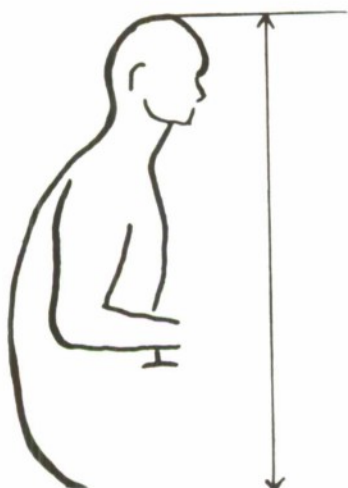
Add .4'' for heavy winter clothing.

How measured: Subject stands (or sits) erect, his right arm and hand extended; shoulders are not thrust forward. The measure is the distance from the wall to the tip of the longest finger.



The following two dimensions are based on measurements of 103 champion civilian drivers and 271 regular civilian drivers.

SITTING HEIGHT (normal)



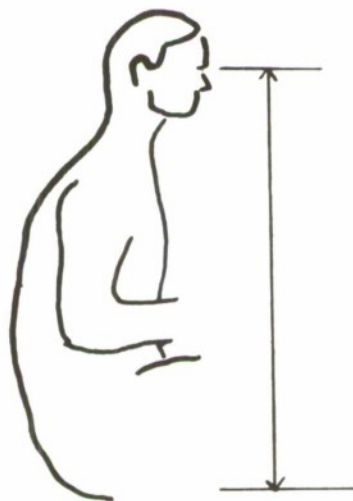
Average: 34.53"

95.5% between 32.05" and 37.01"

Add .6" for heavy winter clothing.

How measured: The subject sits in a normal slumped position. The measure is taken from the seat surface to the top of the head.

EYE HEIGHT (normal)



Average: 29.47"

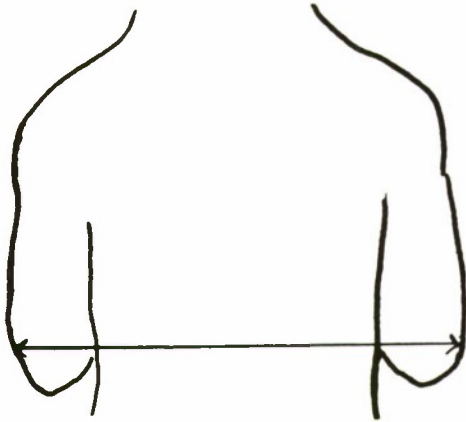
95.5% between 27.22" and 31.72"

Add .4" for heavy winter clothing.

How measured: The distance is measured from the seat surface to inner corner of eye while the subject is sitting in a normal slumped position.

The following five dimensions are based on measurement of over 4,000 flying personnel.

ELBOW BREADTH



Average: 17.15"

95.5% between 14.28" and 20.02"

Add 4.4" for heavy winter clothing.

How measured: subject sits erect, upper arms hanging at his side, forearms extended horizontally. The maximum horizontal distance across the lateral surfaces of the elbows is taken as this measure.

ELBOW HEIGHT (erect)



Average: 9.12"

95.5% between 7.04" and 11.20"

How measured: Subject sits erect. Upper arm hangs at his side and his forearm extends horizontally. The vertical distance from the sitting surface to the bottom of the right elbow is measured.

WAIST HEIGHT (erect)



Average: 9.24"

95.5% between 7.72" and 10.76"

How measured: The subject sits erect. A measure of the vertical distance from the sitting surface to the waist is taken.



GRIP DIAMETER



Average: 1.90''

95.5% between 1.62'' and 2.18''

Subtract .8'' for heavy winter gloves.

How measured: Subject holds a cone around largest circumference he can grasp with his thumb and middle finger just touching. The measure is the cone diameter of this maximum circumference.

HEEL BREADTH



Average: 2.64''

95.5% between 2.34'' and 2.94''

How measured: The right foot is measured behind the ankle bones. The maximum breadth is taken.

TABLE A

Amounts to be added to Various Nude Dimensions for Heavy Winter Flying Clothing
(B-3 Jacket, A-3 Trousers, B-5 Helmet, A-9 Gloves, and A-6 Boots)
(in inches unless specified)

<i>Dimension</i>	<i>Amount to be added</i>
Weight	20 lbs.
Stature	1.9
Head Length	0.4
Breadth	0.4
Height	0.2
Circumference	1.7
Arm	
Total Span	0.4
Span Akimbo	0.8
Anterior Arm Reach	0.4
Shoulder-Elbow Length	0.3
Shoulder Breadth (to bone)	1.3
Shoulder Breadth (across muscle)	0.7
Elbow Breadth (across body)	4.4
Hand Length	0.3
Hand Breadth	0.4
Trunk	
Sitting Height	0.6
Eye Level from Seat	0.4
Shoulder to Seat	0.6
Chest Breadth	0.6
Chest Depth	1.4
Chest Circumference resting	9.1
Abdominal Depth	1.4
Hip Breadth	1.3
Buttock Breadth	1.7
Leg	
Buttock-Knee (sitting)	0.5
Knee Height from Floor	1.8
Knees, Breadth across Both	2.5
Calf Circumference	6.0
Foot Length	2.7
Foot Breadth	1.2

Adapted from Damon, A. Effect of flying clothing on body measurements of Army Air Force Flyers, Memorandum Report ENG-49-695-32, Engineering Division, Aero Medical Laboratory, ATSC, US AAF (Aug. 18) 1943.



PART II

Dynamic body measurement data have not been collected for such large samples as have static measurements. The table below, for instance, is based on measurements of only 10 individuals. The range of movement and means given are for the right hand body members only. Voluntary movements are those which the individual is able to make unaided. Passive movements were effected by another individual moving the body member to its extreme position.

TABLE B

Range of Movement of Body Members (in degrees) *

<i>Body Member and movement</i>	<i>Voluntary</i>			<i>Passive</i>		
	<i>Lower Limit</i>	<i>Upper Limit</i>	<i>Mean</i>	<i>Lower Limit</i>	<i>Upper Limit</i>	<i>Mean</i>
Head						
Rotation (right)	51	95	77	72	114	97
Arm at shoulder						
Flexion (forward)	164	191	179	172	195	185
Extension (backward)	40	71	55	51	93	68
Abduction (side)	113	154	129	116	163	137
Forearm at elbow						
Flexion (bend)	126	150	138	129	155	143
Pronation (turn in)	59	139	91	76	145	105
Supination (turn out)	82	114	99	93	145	114
Hand at wrist						
Flexion (bend down)	73	110	95	80	122	106
Extension (bend back)	32	80	54	67	111	92
Abduction (bend out)	15	40	27	26	45	40
Adduction (bend in)	52	79	66	64	85	74
Thigh at hip joint						
Flexion (forward)	63	119	98	99	124	112
Extension (backward)	26	70	48	41	75	56
Abduction (side)	39	98	70	65	101	79
Internal rotation	39	80	61	45	90	73
External rotation	24	48	37	39	60	46
Leg at knee joint						
Flexion (bend)	118	136	127	128	150	140
Foot at ankle joint						
Plantar flexion (bend down)	18	43	28	22	55	36
Dorsal flexion (bend up)	25	46	37	35	52	44

* From Glanville and Kreezer, *Human Biology*.

Bibliography of Anthropometric Studies:

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- Benton, R. S. *Body sizes of pursuit pilots*. USAF, Air Materiel Command, Wright-Patterson Air Force Base, Aero Med. Lab., Engineering Division, Memo Rep. ENG-49-695-32B, 20 September 1943. (Subjects included 200 fighter pilots and 500 bomber crew members.)
- Brues, A. *Body measurements of female flying personnel*. USAF, Air Materiel Command, Wright-Patterson Air Force Base, Aero Med. Lab., Rep. ENG-49-695-32A, 1 September 1943. (Subjects included 600 pilots and flying nurses.)
- Cosentino, J. A. *Faces and heads*. USA, Chemical Warfare Service Development Laboratory, Mass. Inst. Tech., Memo Rep. No. 135, 1945. (Subjects: 3000 enlisted men)
- Dempster, W. T. *Space requirements of the seated operator*. Wright Air Development Center, Wright-Patterson Air Force Base, WADC Tech. Rep. 55-159, July 1955. (PB 121053)
- Elbel, E. R. *Leg strength and leg endurance in relation to height, weight, and other body measurements*. USAF, School of Aviation Medicine, Randolph Field, Proj. No. 318, Rep. No. 1, 15 August 1945. (Subjects include 163 aviation students, 175 navigators and bombardiers, and 177 aviation cadets.)
- Glanville, A. D. and Kreezer, G. *The maximum amplitude and velocity of joint movements in normal male human adults*. *Human Biology*, 1937, Vol. 9, Pp. 197-211.
- Hooton, E. A. and staff of Harvard University. *A survey in seating*. Gardner, Mass., Heywood-Wakefield, 1945. (Subjects: 2000 civilians, ages 17 to 84)
- Imus, H. A. and Brodden, W. J. *Distributions of measures of interpupillary distance*. NDRC, 24 March 1945, (OSRD Rep. No. 1341), Office of Public Education, Rep. No. 27304. (Subjects: 6500 enlisted men)
- King, B. D., Morrow, D.J., and Vollmer, E. P. *Cockpit studies: The boundaries of the maximum working area for the operation of manual controls*. Naval medical Research Institute, National Naval Medical Center, Bethesda, Md. Project X-651, Rep. 3, July 1947.
- King, B. G. *Measurements of man for making machinery*. *Amer. J. Phys. Anthropol.*, 6:341-351, September 1948.
- McFarland, R. A., et al. *Human body size and capabilities in the design and operation of vehicular equipment*. Harvard School of Public Health, Boston, Mass., 1953.
- O'Brien, R. and Shelton, W. C. *Women's measurements for garment and pattern construction*. Washington, D. C., Government Printing Office, 1941. (Subjects: 10,042 civilians, ages 18 to 82)
- Randall, F. E. *Articulated plaster manikin standards*. AAF, Air Materiel Command, Wright-Patterson Air Force Base, Aero Med. Lab, Engineering Division, Memo Rep. ENG-49-695-28, 5 June 1943. (Subjects: 2960 aviation cadets)



Randall, F. E., Damon, A., Benton, R. S. and Patt, D. I. *Human body size in military aircraft and personal equipment*. USAF, Air Materiel Command, Wright-Patterson Air Force Base, TSEAA-695-43. Tech. Rep. No. 5501, 10 June 1946. (Subjects included 2960 cadets, 584 gunners, 450 female pilots, and 150 flying nurses.)

Sandberg, K. O. W., and Lipshultz, H. O. *Maximum limits of working areas on vertical surfaces*. Office of Naval Research, Special Devices Center, Rep. 166-1-8, April, 1952.

Squires, P. C. *The shape of the normal work area*. Navy Department, Bureau of Medicine and Surgery, Medical Research Laboratory, New London, Conn., Rep. 275, July 1956.



APPENDIX B

LIGHTING AND ILLUMINATION

The purpose of this Appendix is to define the illumination terms used throughout this handbook, and to clarify their interrelationships. A complete discussion of illumination and lighting is beyond the scope of this handbook. We are presenting this limited discussion for the benefit of readers who are not familiar with the basic photometric units normally found in the research literature.

The remainder of this Appendix contains a discussion of three basic qualities of light and a hypothetical example of conversion from one to another to illustrate their interrelationships.

1. Intensity – This is a measurement at the light source and is rarely used in illumination research. The basic term used to describe a light source is luminous flux (the rate of flow of visible radiant energy) and is given in lumens. Any source providing one lumen per unit of solid angle is said to have an *intensity* of one candle.

It would be desirable to have a formula by which the wattage of electric lamps could be converted into lumens or candles. This is, however, not feasible, since the lumen rating of a bulb depends on many factors besides wattage. The main determining factor is the efficiency of the source, which varies (for tungsten bulbs) from 6 to 40 lumens per watt depending on such conditions as the following:

- a. Voltage – Higher voltages tend to produce lower efficiencies.
- b. Bulb content – Vacuum bulbs are lower in efficiency than gas filled ones.
- c. Construction – Those built for longer life and rough service have lower efficiencies than those built for short life and general lighting.

Lumens can be translated into candles by the formula: Candles equals 4π lumens. Thus one candle equals 12.57 lumens, and one lumen equals 0.0795 candles. Knowing the lumen (or candle) rating of a particular bulb can be of some help to the designer of equipment or workplaces, but this information cannot be used to arrive at precise illumination or brightness measurements.

2. Illumination – This can be defined as the amount of light striking a surface and is a function of the intensity of the light source and the distance of the surface from that source. Illumination can be expressed in several ways including lumens per square meter, but is usually given as foot-candles (ft.-C) which is equivalent to lumens per square feet. (One foot-candle is equal to 10.764 lumens per square meter). One foot-candle is the amount of light cast by a 1 candle source at a distance of one foot. The number of foot candles can be determined by the following formula:

$$\text{Ft.-C} = \frac{\text{cp}}{D^2}$$

where Ft.-C is the number of foot-candles falling on each square foot of surface, cp is the candlepower of the source of light, and D is the distance of the surface from the source.

3. Brightness – Brightness is a measure of the amount of light reflected from a surface. It is determined by the intensity and quality of the light source, distance of the surface from the source, and the reflecting quality of the surface. The most common unit of measurement is the millilambert (mL) which is equal to 1/1000 of a lambert (L). A lambert is defined as the brightness of a perfectly diffusing surface emitting one lumen per square centimeter, while a foot lambert is defined as the brightness of a perfectly diffusing surface emitting one lumen per square foot. The various units which may be used in measuring brightness, along with their conversion factors are given in the following table.

CONVERSION FACTORS FOR BRIGHTNESS UNITS*

	Ft.-L	L	mL	C/in ²	C/ft ²	C/cm ²
Foot-Lamberts	1.0	1.076×10^{-3}	1.076	2.210×10^{-3}	3.183×10^{-1}	3.426×10^{-4}
Lamberts	9.290×10^2	1.0	1×10^3	2.054	2.957×10^2	3.183×10^{-1}
Millilamberts	9.290×10^{-1}	1×10^{-3}	1.0	2.054×10^{-3}	2.957×10^{-1}	3.183×10^{-4}
Candles per sq. in.	4.524×10^2	4.869×10^{-1}	4.869×10^2	1.0	1.440×10^2	1.550×10^{-1}
Candles per sq. ft.	3.142	3.382×10^{-3}	3.382	6.944×10^{-3}	1.0	1.076×10^{-3}
Candles per sq. cm.	2.919×10^3	3.142	3.142×10^3	6.45 ²	9.290×10^2	1.0

* From Baker and Grether, *Visual Presentation of Information*

ILLUSTRATION OF CONCEPTS

Manufacturers' lamp catalogs usually give a lamp's rating in terms of lumens. To illustrate the units described in preceding paragraphs we will take the manufacturer's rating for a particular bulb and determine the *Intensity*, *Illumination*, and *Brightness* that might be obtained with such a bulb. This exercise is merely illustrative and should not be construed as providing a means of determining precise measurements.

Let us assume that the manufacturer rates a 100 watt lamp at 1885 lumens. (This is a realistic figure though not specific to any known lamp.) Let us further assume that the working area will be five feet from the light source and that it will have a surface which reflects 50% of the light striking it.

We can then determine the different measurements in the following way:

Intensity – Since one lumen equals 0.0795 candles, 1885 lumens equals 150 candles (1885 x 0.0795). Intensity then is 150 candles.

Illumination – To determine illumination we can apply the formula:

$$\text{Ft.-C} = \frac{cp}{D^2}$$

thus: $\text{Ft.-C} = \frac{150}{5^2}$ The Illumination is 6 foot-candles.



Brightness — If the surface were perfectly diffusing, brightness would be equal to 6 foot lamberts, but the reflectance of our surface is 50%. Therefore, the brightness is 3 foot lamberts ($50\% \times 6$). This can be converted into the more common millilamberts by multiplying by 0.929. The brightness in millilamberts is thus 2.8.

Additional sources of information on Illumination:

Handbook of Human Engineering Data. Part III, "Vision," 1952.

Survey Report on Human Factors in Undersea Warfare, Part I, "General Visual Problems," 1949.

McCormick, E. J. *Human Engineering*. Chapter 2, "Light and Seeing," and Chapter 3, "Illumination," 1957.

Baker and Grether, *Visual Presentation of Information*. Chapter 6, "Lighting," 1954.



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Baker, C.A. and Grether, W.F. *Visual presentation of information*. Wright Air Development Center, Wright-Patterson Air Force Base, Ohio. WADC TR 54-160, August, 1954.

This report is a compilation of general human engineering recommendations on visual displays. It should aid the engineer in providing the most satisfactory visual presentations of information. Subjects covered include Mechanical Indicators, Warning Devices, Cathode Ray Tubes, Printed Materials, Instrument Panel Layout, and Lighting.

Berkun, M. M. and Van Cott, H. P. *Checklist of human engineering evaluation factors (plans inspection) "CHEEF 1."* Wright Air Development Center, Ohio, WADC (AF-WP-(B)-0-23 Nov. 56 150), September 1956. (American Institute for Research, AIR-24-56-FR-135)

This checklist is intended as an aid in the human engineering evaluation of developmental weapons, sub-systems and support equipment. It is to be used to evaluate human engineering characteristics from drawings, blueprints and other written plans.

Ely, J. H., Thomson, R. M., and Orlansky, J. *Layout of workplaces*. Aero Medical Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio. WADC TR 56-171, September 1956.

A compilation of human engineering recommendations concerning various aspects of workplace layout. The four main sections are entitled: General Considerations, Workplace Dimensions, Location of Controls and Displays, and Direction-of-Movement Relationships.

Ely, J. H., Thomson, R. M. and Orlansky, J. *Design of controls*. Aero Medical Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio. WADC TR 56-172, November 1956.

Part I of this report gives general rules for control selection and describes the characteristics of nine specific controls. Part II contains a general discussion of control-display ratio, control forces, coding, and problems of inadvertent activation as well as detailed design recommendations for the nine specific controls.

Fitts, Paul M. *Psychological research on equipment design*. United States Government Printing Office, Washington, D.C. USAAF, Psychology Service Report 19, 1947.

A summary of human engineering research problems and work done on some of them by Air Force psychologists during World War II. Seventeen research projects, primarily in the design of controls and displays, are described.

Floyd, W. F. and Welford, A. T. (Ed.) *Symposium on human factors in equipment design*. Ergonomics Research Society Proceedings, Vol. 2. H. K. Lewis & Co., London. 1954.

This book is a compilation of the fifteen papers presented during the symposium. Included are papers on: Body Sizes and Work Spaces, Body Measurements of the Working Population, Chairs and Sitting, Perceptual Problems Involved in Observing Displays, Equipment Layout, and others.

Folley, J. D., Jr. and Altman, J. W. *Guide to design of electronic equipment for maintainability*. Wright Air Development Center, Wright-Patterson Air Force Base, Ohio. WADC TR 56-218, April 1956. (American Institute for Research, AIR-197-56-FR-121)

The purpose of this guide is to present recommended design practices for maximizing the ease with which electronics equipment can be maintained. In addition to specific design recommendations, factors to be considered in maintainability design and steps in designing a maintainability program are described.

Hunter, G., et al. *Suggestions for designers of electronics equipment*. United States Naval Electronics Laboratory, San Diego, California. 1958.

This pocket-sized booklet contains suggestions and recommendations to aid electronics equipment manufacturers to produce simpler, more economical, and more reliable electronics equipment.

Kennedy, J., et al. *Handbook of human engineering data for design engineers*. Tufts Institute for Applied Experimental Psychology, Medford. Office of Naval Research, Special Devices Center Technical Report No. SDC 199-1-2, 1952.

A comprehensive volume which brings together and summarizes a large mass of data in the fields of body measurements, vision, hearing, skin sensitivity, and motor performance. It was published as a reference tool to be used by design engineers in seeking answers to design problems.

Krumm, R.L. and Kirchner, W.K. *Human factors checklists for test equipment, visual displays, and ground support equipment*. Air Force Special Weapons Center, Kirtland Air Force Base, New Mexico. AFSWC TN 56-12, February 1956. (American Institute for Research, AIR-186-56-FR-117)

A series of checklists intended as an aid in the human engineering analysis of general design features of certain types of equipment. The checklists can be used to identify human factors design deficiencies, point out equipment shortcomings requiring improvement, and suggest the relative seriousness of these shortcomings.

Lockheed Aircraft Corporation, Missile Systems Division. *Designing for electronic maintainability*. Public Relations Department.

This cleverly illustrated booklet presents many human engineering recommendations on the design of electronic equipment for ease in field maintenance. Included is an expanded human engineering checklist of over 80 design items.

McCollom, Ivan N. and Chapanis, A. *A human engineering bibliography*. San Diego State College Foundation, San Diego, California. Technical Report No. 15, 1956.

The most complete bibliography of human engineering sources. It attempts to include only items pertaining to human engineering design, in order ". . . to place in the hands of design engineers a usable source of human engineering information which can be applied directly to the problems related to the designing of equipment. . ." There are sixteen sections containing 5,666 references.

McCormick, Ernest J. *Human Engineering*. McGraw-Hill, New York, 1957

One of the few text book type references in human engineering. It is a non-technical well illustrated and documented book which summarizes and interprets research in human engineering, i.e., "the design of equipment and the adaptation of work environment for optimum human use."



National Research Council Panel on Psychology and Physiology. *A survey report on human factors in undersea warfare*. Committee on Undersea Warfare, National Research Council, Washington, D.C., 1949.

This volume presents a general summary of the status of knowledge (1949) with reference to the role of the human factor in undersea warfare. Among the topics covered are: Design and use of visual displays, design and arrangement of operating equipment, and auditory problems.

Office of Naval Research. *Human engineering bibliography (1955-1956)*. Report ACR-24 Human Engineering Information and Analysis Service, Institute for Applied Experimental Psychology, Tufts University. (ASTIA AD-149950). October 1957.

One of a planned series of annual annotated bibliographies pertinent to human engineering. It is designed for rapid and easy access to literature pertinent to the work of personnel responsible for human factors considerations. The bibliography is organized in five parts: (1) a topical outline of over 300 topic headings established for this bibliography, (2) an index which associates the approximately 1400 citations with the topic headings, (3) an alphabetic index of common human engineering research terms, (4) an annotated bibliography of some 1400 citations, and (5) an index of the authors of these citations.

Psychological Research Associates. *Manual of human engineering principles for mine test set design*. Bureau of Ordnance, Department of the Navy, Washington, D.C. May 1956.

A manual of human engineering principles to assist the engineer in designing mine test sets for greater operator accuracy and efficiency. Sections are devoted to labeling, coding, construction features, control placement, indicators, and cables.

Spector, Paul, Swain, A. D., and Meister, D. *Human factors in the design of electronics test equipment*. Rome Air Development Center, Griffiss Air Force Base. RADC TR 55-83, April 1955. (American Institute for Research, AIR-184-55-FR-94)

A description is presented of problems encountered by maintenance men in the utilization of ground electronics test equipment. Detailed recommendations are made for the human engineering design of test equipment. An outline of a method by which human engineering principles can be applied to the design of test equipment is also presented.

Vandenberg, J. D. and Goldsmith, C. T. Human factors engineering: 1. Man and machine, 2. Design for seeing, 3. Design for hearing, 4. Design for controls. *Machine Design*. April 17, May 1, May 15, and June 1, 1958.

This four article series on human factors engineering contains many human engineering design recommendations. The articles are written for the design engineer, in his own language and appear in one of his own publications.

Van Cott, H. P. *Checklist of human engineering evaluation factors (design inspection)* "CHEEF 2." Wright Air Development Center, Ohio, WADC (AF-WP-(B)-0-23 Nov 56 150), September 1956. (American Institute for Research, AIR-24-56-FR-134)

A checklist intended as an aid in the human engineering evaluation of developmental weapons, sub-systems, and support equipment. It is to be used to evaluate human engineering characteristics from mockups, prototypes, and other initial pieces of equipment during their design inspection.

Van Cott, H. P. and Altman, J. W. *Procedures for including human engineering factors in the development of weapon systems*. Wright Air Development Center, Wright-Patterson Air Force Base, Ohio. WADC TR 56-488, October 1956. (American Institute for Research, AIR-24-56-FR-139)

This volume presents a systematic procedure for insuring that human factors are considered at each appropriate step in the development of weapon systems. Information is given on human capabilities and limitations; and procedures for assessing and solving human engineering problems are suggested.

Woodson, W. E. *Human engineering guide for equipment designers*. University of California Press, Berkeley, 1954.

To aid the designer in making optimum decisions wherever human factors are involved in man operated equipment, this Guide provides a central source of information about the human operator. Chapters are included on Workspace, Vision, Audition, and Body Measurements.

AFBM Exhibit 57-8A. *Human engineering design standards for missile system equipment*. Air Force Ballistic Missile Division, Inglewood, California, November 1958.

Prepared for design engineers, this document sets forth design principles and practices, both general and specific, to be used in designing equipment for maximum operator utilization. The seven sections are entitled: General Requirements, Visual Displays, Controls, Physical Characteristics, Ambient Environment, Work Place Characteristics, and Hazards and Safety.

Handbook of instructions for aircraft designers. (HIAD) Tenth Edition. Air Research and Development Command, Wright-Patterson Air Force Base, Ohio. ARDCM 80-1.

This three volume manual is a central source of design requirements and experience data for use by research engineers and designers of USAF piloted aircraft and guided missiles. The three volumes are entitled: Piloted Aircraft, Guided Missiles, and Aircraft Design Control Drawings.

Handbook of instructions for ground equipment designers. (HIGED) First Edition. Air Research and Development Command, Wright-Patterson Air Force Base, Ohio. ARDCM 80-5.

Under one cover this manual presents the general requirements for USAF ground equipment. It provides guidance as to military requirements, criteria, and principles which apply to USAF ground equipment.

Handbook of instructions for aircraft ground support equipment designers. (HIAGSED) First Edition. Air Research and Development Command, Wright-Patterson Air Force Base, Ohio. ARDCM 80-6.

A central source of design requirements and experience data applicable to USAF ground support equipment for piloted aircraft and guided missiles.



Selected Military Specifications

MIL-M-6B and -1. *Meters, electrical indicating, panel type, 2½ inch and 3½ inch, general specifications for.* 10 May 1957.

MIL STD 130. *Identification marking of US military property.* 4 March 1953.

MIL-M-8090 (USAF). *Mobility requirements, ground support equipment, general specifications for.* 14 March 1958.

MIL-G-8402 (USAF). *Gage, pressure, dial indicating, general specifications for.* 7 April 1955.

MIL-S-8512. *Ground support equipment, general requirements for.* 8 January 1958.

MIL-M-16034. *Meters, electrical indicating (switchboard and portable types).* 2 January 1953.



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